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Design features of portable wheelchair ramps and their implications for curb and vehicle access

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Abstract—This study evaluated a range of portable wheelchair ramps to highlight the effect of different product features on ease of use when wheelchair users climb curbs or access vehicles. Twelve portable ramps were evaluated. Although all the ramps were designed to load powered wheelchairs into motor vehicles, they were manufactured in different designs. The ramps were based on a "singlewide" platform or "channel" design. Some ramps had fixed dimensions, whereas others could be reduced in size because they were telescopic or designed to allow folding. Overall, the ramps could be divided into four subgroups on the basis of their key features. These were horizontally and longitudinally folding ramps, telescopic ramps, and ramps with fixed dimensions. The telescopic ramps could be subdivided into "U"-shaped gutter ramps and reverse profile ramps. Product appraisals and trials involving wheelchair users and caregivers of wheelchair users were done to evaluate each of these ramp designs. Although wheelchair ramps are available in a wide range of designs and configurations, we found that no single ramp design successfully met the needs of all wheelchair users or their caregivers. The evaluation highlighted a number of specific problems and potential hazards. Some ramps were found to move during a maneuver, showed poor stability when used with some vehicles, or were too narrow to allow wheelchair castors to pass through the channel without jamming. Some features, such as handles and locking mechanisms, influenced the ease with which the caregivers could use the ramps. Wheelchair users preferred the wide platform ramps because they were able to drive up these with ease and little preparation. The caregivers preferred folding or telescopic channel ramps because these were easier to handle and store.

Key words: assistive technology, equipment design, portable ramps, wheelchair ramps.

INTRODUCTION

People with a range of mobility problems use powered wheelchairs to improve freedom of movement around a variety of environments, including the home, place of work, or local community and often without the assistance of a caregiver. However, powered wheelchairs are low-speed devices and many are not designed for use outdoors or for extended periods. Therefore, if wheelchair users must take long journeys away from their homes, they usually have to transport a powered wheelchair in a

Abbreviations: UK = United Kingdom, WTORS = wheelchair tie-down and occupant restraint system.

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motor vehicle and will often need the help of their caregivers to transfer and stow the chair. In these circumstances, several options are available to the caregiver. One method is for the user to transfer into a standard car seat and for the caregiver to dismantle and stow the wheelchair. This method may be preferred for reasons of safety and cost [1]. However, it involves the caregiver manually handling both the user and the wheelchair and his or her expertise and time in dismantling the wheelchair.

An alternative option is for the user to remain seated in the powered wheelchair and for the wheelchair and user to be secured in the vehicle with a wheelchair tie-down and occupant restraint system (WTORS). Several alternative methods can be found by which a wheelchair can be loaded into a vehicle, including a tail lift, a hoist, a fold-down wheelchair ramp, or portable wheelchair ramps. Tail lifts, hoists, and fold-down ramps require costly vehicle adaptations and cannot be installed in smaller vehicles. Portable wheelchair ramps offer a cost-effective solution to this problem, with the additional advantage that they can be used to access steps, buildings, and other transportation systems. Portable wheelchair ramps are also commonly used as a temporary measure until permanent ramps can be constructed from wood, concrete, or metal and fitted [2]. An earlier evaluation of portable building access ramps revealed that weight, length, and width were key design features that influenced safety and usability [3,4].

The design, size, portability, and ease of use of portable wheelchair ramps currently available on the market vary greatly. However, two basic designs exist and these are "singlewide" platform and channel ramps. One limitation reported to occur with channel ramps is that only caregivers who are physically able to walk between the channels while pushing the wheelchair at shoulder height can use them [5]. This study evaluated a range of portable wheelchair ramps to highlight the advantages and disadvantages of different designs and to assess their impact on ease of use when users access vehicles or climb curbs.

METHODS

Identification and Selection of Ramps

We consulted manufacturers and gathered information from suppliers' literature and the Hamilton Index [6]. Over 300 wheelchair ramps were identified with different design features and dimensions. We selected a sample of ramps to represent different design features using the following predefined inclusion criteria:

- Ramps suitable for use with a motor vehicle.
- Ramps between 2 to 3 m in length. This dimension was chosen because ramps of this length would not exceed the maximum gradient of 1:4 recommended by suppliers of powered wheelchairs when used with vehicles that have a floor height of 56 cm. This mean floor height was derived from a convenience sample of 10 "estate" cars and "people carriers."
- Ramps with a minimum load-carrying capacity of 250 kg. This threshold was based on the mean weight of a convenience sample of 30 powered wheelchairs and scooters plus the mean maximum user weight specified by manufacturers.

Initially, 19 ramps were found to meet these criteria; however, 5 were excluded because they shared the same design characteristics. On the basis of the following design features, we categorized ramps—

- Composed of a singlewide platform.
- Composed of two separate channels.
- That folded about a horizontal axis.
- That folded longitudinally.
- That reduced in length telescopically.
- With fixed dimensions.
- With reverse profile flanges (i.e., the inner edge of the channel turned down rather than up).

The individual specification of the 12 ramps evaluated can be seen in **Table 1**, and examples of these designs can be seen in **Figures 1** to **5**. We have included a list of the models used in **Appendix A (**found in the online version only); however, these are only examples of each design and other manufacturers produce similar devices.

Evaluation Methods

The portable wheelchair ramps were evaluated in three stages. These stages are described in the following subsections.

Product Appraisals (Stage 1)

On delivery of the ramps, a multidisciplinary team, including a research physiotherapist, occupational therapist, rehabilitation engineer, and ergonomist, undertook an objective appraisal. This appraisal assessed the following specifications of each product:

- General finish (e.g., paint imperfections, metal burrs, and sharp edges)

Table 1.
Specification of ramps included in evaluation (channel, reverse profile channel, and wide designs).

Ramp Code	Basic Design	Method for Reducing Size	Material	Surface Type	Total Weight (kg)	Weight of Each Section (kg)	Max Length (mm)	Min Length (mm)	Gutter Depth (mm)	Inner Width (mm)	Outer Width (mm)	Instructions	Handles
1	Channel	Horizontal Folding	Aluminum	Patterned	22.8	11.4	3,050	1,550	46	150	160	No	Yes
2	Channel	Horizontal Folding	Aluminum	Pressed	14.0	7.0	2,100	1,080	45	185	210	Yes	Yes
3	Channel	None	Aluminum	Pressed	11.6	5.8	2,020	2,020	45	185	210	Yes	Yes
4	Channel	Telescopic	Aluminum	Gritty Paint	28.4	14.2	3,050	1,680	45–52	190	250	Yes	No
5	Channel	Telescopic	Aluminum	Glass Paper	16.0	8.0	2,160	870	43	198	260	No	No
6	Channel	Telescopic	Aluminum	Glass Paper	17.2	8.6	2,270	1,380	38–45	196	260	No	No
7	Reverse Profile Channel	Telescopic	Aluminum	Gritty Paint	38.4	19.2	3,010	1,740	60	200	250	Yes	No
8	Reverse Profile Channel	Telescopic	Aluminum	Glass Paper	17.6	8.8	1,940	1,090	46–58	230	280	No	No
9	Wide	None	Aluminum	Patterned	18.2	18.2	2,000	2,000	41	750	760	No	No
10	Wide	3 Pieces	Aluminum	Glass Paper	25.0	8.8 + 7.4	1,920	1,110	46–58	780	820	No	No
11	Wide	Longitudinal Folding	Fiberglass	Glass Paper	17.8	17.8	2,000	2,000	60	780	810	No	Yes
12	Wide	Horizontal Folding	Aluminum	Glass Paper	23.2	23.2	2,000	1,020	45	770	820	Yes	Yes

- Availability, length, and clarity of written instructions
- Availability and clarity of any safety warnings
- Design features (e.g., capacity for wheelchair and caregiver access to the vehicle; capacity to fold, carry, and store)
- Weight and dimensions
- Ease of handling

Professional Trials (Stage 2)

The aim of the professional trials was to determine if the ramps would remain in situ or move while a powered wheelchair and occupant were being loaded and unloaded. Although users are advised to load wheelchairs into a vehicle when empty and to disengage the power supply, some users choose to disregard such advice. We felt it was important, therefore, to include these trials to highlight any potential hazards. A research physiotherapist and ergonomist conducted the professional trials using the following:

- A rear-wheel-drive powered wheelchair (Invacare Phoenix).
- A 100 kg anthropomorphic dummy (chosen to simulate an adult wheelchair user).
- A Ford transit van (chosen because it provides sufficient headroom to allow loading and unloading of an Invacare Phoenix wheelchair and dummy. This model van was also selected because it represents the family-size class of vehicle commonly used by private wheelchair users.).

Since the ramps varied in length, the professional trials encompassed a range of gradients between 1.0 in 4.7 (12°) and 1 in 23 (20°).

At the beginning of each trial, the ramp was positioned at the rear of the vehicle and its position on the floor was marked with tape. The loaded wheelchair was driven forward up the ramp and reversed down by means of the wheelchair controls. Each ramp was tested 10 times, and after each ascent and descent, the position of the ramp was checked against the position marked originally. Any movement of the ramp greater than 10 mm was noted.

User Trials (Stage 3)

We recruited 14 wheelchair users and 13 caregivers of wheelchair users to undertake standard user trials, to be described shortly. This pool of volunteers ensured that

Figure 1.
Wide ramp that folds about a horizontal axis.

Figure 2.
Wide ramp that folds longitudinally.

each ramp was tested at least five times by caregivers and five times by wheelchair users. We completed the trials independently, rather than in pairs, to ensure that each person's attitudes and experiences did not influence others. The number of tests that each participant completed varied between two and six and depended upon the tolerance and functional abilities of each individual. We obtained approval to carry out these evaluations from the Local Research Ethics Committee, and each participant gave informed consent.

Caregiver User Trials. Each caregiver was asked to undertake the following activities and standard instructions as listed:

- Place one end of the selected ramp on the sill of the vehicle.
- Load the powered wheelchair into the vehicle.
- Collapse or fold the ramp and place into the vehicle.
- Remove the ramp from the vehicle.
- Open the ramp and place it in position on the vehicle sill.
- Remove the powered wheelchair from the vehicle.

The caregivers were asked to report any difficulties experienced when lifting and handling and to rate the ease with which they could maneuver the wheelchair up and down the ramp. A powered chair was used during the trials because a manual wheelchair can usually be loaded into a vehicle without ramps.

Wheelchair User Trials. Because portable ramps can also be used to access steps and buildings, additional trials were designed to evaluate this secondary function. A test rig was constructed to replicate the height of a standard step (**Figure 6**). It is recommended that ramps

Figure 3.
Telescopic channel ramps.

Figure 4.
Fixed-dimension channel ramps.

be used at a gradient of 1:12 [7], and therefore, an adjustable height rig was constructed to replicate this gradient. The rig consisted of a raised level platform and was fitted at one end with a fixed wide ramp. Each portable ramp was used in turn to access the freestanding end of the rig platform.

During the trials, the wheelchair users were asked to drive up the portable ramp, across the rig, and down the fixed wide ramp. We reversed this procedure on each occasion to allow the user to drive both up and down the test ramp.

The users were asked to rate how much difficulty they experienced when aligning the wheelchair with the ramp and when driving up and down it. They were also asked to rate how safe they felt during each stage of the maneuver.

RESULTS

Product Appraisals

Several ramps showed a poor level of finish, with sharp edges, burrs, and some evidence of poor quality welding or painting. Although a few exceptions were found, the level of finish was proportionate to the price of the product. Only five ramps were supplied with instructions and the level of detail was not always comprehensive. Although one might assume that ramps are relatively simple devices, which can be used without instructions, our experience indicates that this is not the case, because a number of participants tried to use the ramps incorrectly. Half the ramps had no visible warning signs or stickers attached to them. The remainder carried some

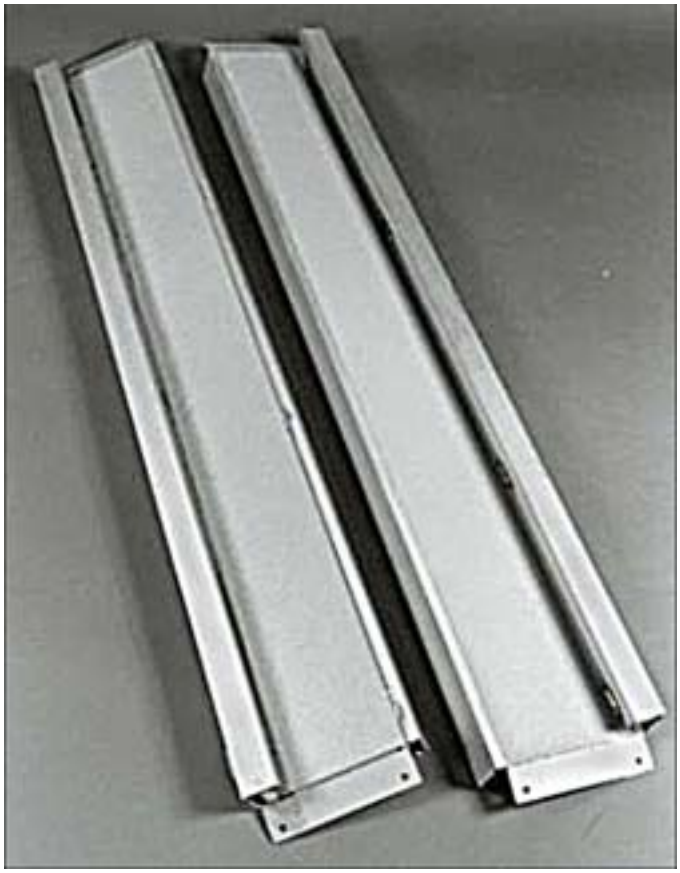

Figure 5.
Reverse-profile channel ramps.

warnings and included information, for example, on how to carry the ramps and attach them to a vehicle.

The minimum carrying weight for each detachable section of the ramps ranged between 5.8 kg and 23.2 kg. Half the ramps included sections that weighed 8 kg but five had sections that weighed over 14 kg. In view of the dimensions of the ramps and their mass, some were not suitable for lifting from ground level, particularly by slight, older, or frail people.

Ramps that are manufactured in a "U" or gutter shape are designed to prevent wheelchair castors from falling off the edge of the ramp. The depth of the gutter of the single channel ramps varied between 43 mm and 60 mm. The reverse channel ramp design has been introduced to overcome the obstructions that occur between castors and the gutter edge of standard U-shaped channel ramps. Although the reverse channel ramps were not compatible with our test vehicle or rig, we have included the product appraisal findings for comparative purposes.

Figure 6.
Test rig used during user trials.

Five of the ramps were fitted with handles to assist with carrying. Two of the telescopic ramps had no locking mechanisms, and therefore, the ramp sections were found to slide apart if they were carried in a vertical position. Those that did have a locking mechanism (**Figure 7**) were easier to lift and carry.

Professional Trials

The results of the professional trials are summarized in **Table 2**. Ramps 3, 5, 11, and 12 moved between 10 mm and 20 mm while the wheelchair and the anthropomorphic dummy were unloaded from the vehicle and Ramp 6 moved more than 10 mm during loading.

On two occasions, during testing of Ramp 1, the front castor of the wheelchair turned sideways in the channel (**Figure 8**). Although the castor was jammed and could not turn, the rear wheels continued to be powered. As a consequence, the torque from the rear wheels caused the ramp to move away from the vehicle and fall to the floor.

The form and surface of the gutters also caused difficulties when the channel ramps (Ramps 1–6) were used because these factors prevented the wheelchair from moving freely unless the footplates were raised to a level that was unsuitable for the leg length of the anthropometric dummy.

Three ramps (7, 8, and 10) could not be included in the professional trials because they were not compatible with the test vehicle. These ramps had reverse profile gutters and could not be positioned in a stable position on the vehicle sill (**Figure 9**). Although an alternative style of vehicle was tried (SEAT Alhambra People carrier), similar difficulties occurred. In this case, the reverse profile flanges came into contact with the rear bumper, and this prevented the ramps from being positioned on the sill in a level and stable position without protruding above floor level.

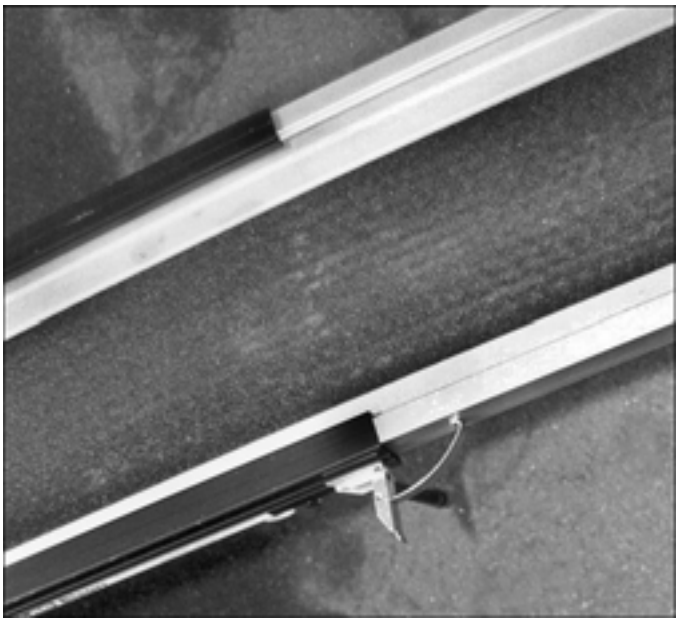

Figure 7.
Ramp with a locking mechanism.

User Trials

Four ramps were excluded from the user trials. Ramps 7, 8, and 10 were found to be incompatible with both the test vehicle and rig. Ramp 9, a singlewide platform ramp, was excluded because it was considered to be too heavy (weighing 18.2 kg) and large to be handled safely within current manual handling guidelines [8].

Caregiver User Trials

Depending on the ramp design, caregivers adopted different methods when loading and unloading the wheelchair. When using wide ramps, all but 1 of the 13 caregivers chose to drive the powered wheelchair up and down the ramps using the wheelchair controls. When testing channel ramps, however, the participants chose to walk between the ramps and push the powered wheelchair up and down. Although they made no comments about pushing the chair, several participants criticized the position of the handles and the locking mechanisms on the channel ramps (see **Figures 4** and **7**). The participants found that these metal protrusions came into contact with their legs when walking between the pair of channel ramps and commented, for example, “If they had thought, they could have put the handle on the other side.”

The findings of the caregiver user trials are summarized in **Table 3**. Three caregivers reported difficulties when unfolding and extending Ramps 1 and 5. These problems occurred because they required a large arm span to manipulate the ramps effectively and to operate the folding and unfolding mechanism.

Table 2.
Results of professional trials.*

Ramp Code	Basic Design	No. of Times Ramp Moved >10 mm (No. of Tests = 10)		Gradient (°)
		Unloading	Loading	
1	Channel	3	0	12
2	Channel	0	0	19
3	Channel	3	0	20
4	Channel	0	0	13
5	Channel	5	0	20
6	Channel	0	2	19
9	Wide	0	0	19
11	Wide	1	0	20
12	Wide	1	0	19

*Ramps 7, 8, & 10 could not be included in professional trials because of incompatibility with test vehicles.

Eight caregivers found that it was difficult to store Ramp 3 inside the test vehicle because of its length. Difficulties were also experienced when loading and storing Ramps 11 and 12 because of their length and width. The caregivers reported no difficulties in the use of Ramp 6. All caregivers stated that they preferred the folding or telescopic channel ramps above the other designs because they were easier to handle and stow in the vehicle.

Figure 8.
Front wheelchair castor jammed in channel ramp.

Wheelchair User Trials

Risk assessments were carried out with each participant before the trials to identify any potential hazards. As a consequence of these assessments and of the findings derived from the professional trials, only one participant was able to test Ramp 1.

We found the wide ramps presented no problems to the wheelchair users. The users encountered difficulties when using the channel ramps; however, these occurred because each user could not align his or her wheelchair easily with the channel ramps before ascending and descending.

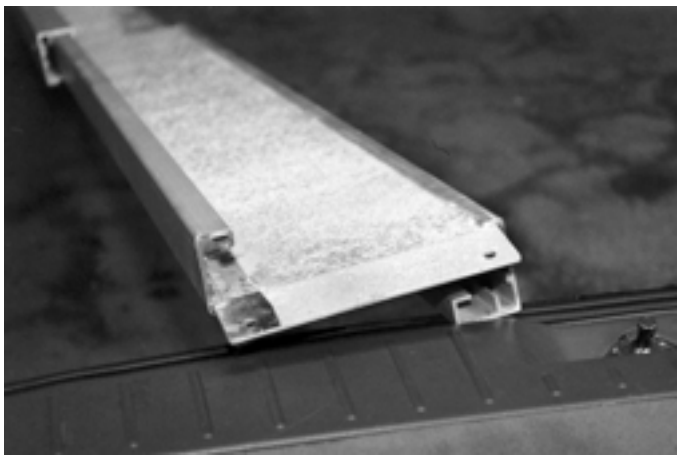

Figure 9.
Ramp showing incompatibility with vehicle rear sill.

Table 3.
Results of caregiver user trials.

Ramp Code and Type	No. of Users	Difficulty Lifting	Difficulty Carrying	Difficulty Unfolding/ Extending	Difficulty Placing Ramp on Vehicle	Difficulty Driving Up	Difficulty Driving Down	Difficulty Storing Ramp in Vehicle
1: Channel	3	1	1	3	1	0	1	0
2: Channel	7	0	0	1	0	0	1	0
3: Channel	8	0	0	0	0	0	0	8
4: Channel	1	0	0	0	0	0	0	1
5: Channel	3	0	1	3	1	0	0	0
6: Channel	6	0	0	0	0	0	0	0
7: Reverse Profile	*	*	*	*	*	*	*	*
8: Reverse Profile	*	*	*	*	*	*	*	*
9: Wide	*	*	*	*	*	*	*	*
10: Wide, Reverse Profile	*	*	*	*	*	*	*	*
11: Wide	4	0	0	0	2	0	2	4
12: Wide	3	2	1	2	0	2	0	3

*Ramps not tested because of exclusion following risk assessment or incompatibility with vehicle.

All wheelchair users stated that they preferred the singlewide platform ramps above the other designs. The reasons they cited for this preference were that the wide ramps "needed less concentration," they had "no problems with alignment," and they were "much quicker to use."

DISCUSSION

Portable wheelchair ramps are available in a wide range of designs, materials, and configurations. Therefore, the needs of wheelchair users and caregivers should be able to be accommodated, at least partially, if the needs are identified clearly and ramps are selected with the appropriate combination of features. As expected, our results suggest that no single design or individual product can meet the needs of all users. However, we have included design guidelines in **Appendix B** (found in the online version only), which lists the key advantages and potential limitations of several designs and product features.

Clear information and instructions are required to ensure that ramps are used correctly. They should clearly state, for example, that portable wheelchair ramps are designed to load unoccupied wheelchairs only and that hazards may occur if wheelchairs are loaded with an occupant. Since less than half the products we received were delivered with instructions and the clarity of those we did receive was generally poor, this is clearly an area in which improvements could be made. Safety warning stickers were also limited in both number and level of detail. It is probable, therefore, that some users will purchase portable wheelchair ramps that are not compatible or stable when used in combination with the vehicle they own. Clearly, these aspects of quality control could be improved quite easily and at little extra cost.

Although the ramps that we evaluated were described as portable in the product literature, some were heavy and difficult to handle. We excluded one ramp from the user trials because of these factors; it would not have been possible for one person to handle the device within current moving and handling guidelines [8]. Similarly, four ramps could not be placed in the vehicle's load space because of their weight, length, or width. Together these findings suggest that some products, which are described or marketed as portable devices, might not be categorized or usable as such by some users.

The caregivers showed a clear and equal preference for the folding and telescopic channel ramps above the ramps that were wide and had fixed dimensions. Although they commented about the position of the handles and the locking mechanisms, the caregivers found it easier to lift and carry ramps that had these accessories. In contrast, the wheelchair users preferred the singlewide platform ramps because these seemed to require less effort and concentration when driving up or down.

One set of channel ramps had gutters that were too narrow to allow the wheelchair castors to move freely, and consequently, these jammed and created a potential hazard because the ramps, the wheelchair, and the anthropomorphic dummy fell to the floor. This incident highlights that it is essential for clear information about the product's characteristics, potential limitations, and compatibility issues to be provided with ramps and in the accompanying product literature. Clearly, manufacturers cannot possibly provide an exhaustive list of the models of wheelchair or van with which a ramp is compatible, but they should be able to highlight the importance of this factor and to include guidance notes.

All the tests in this evaluation were carried out in optimal conditions, on dry and level ground, and in these circumstances, most of the ramps performed well when tested for slippage. However, in wet weather, the chances of wheel slippage would increase and the stability of any ramp would be reduced if positioned on uneven ground. The impact of these environmental factors could be explored in future work. Similarly, there are other design features, which we were not able to consider here (for example, wider channels, rubber feet, vehicle mating plates), that would be worthy of further investigation.

CONCLUSIONS

No single ramp design met the needs of all the wheelchair users or caregivers. However, several practical problems were noted that related to the size, mass, storage, ease of use, and handling of the ramps.

Safety information and clear instructions are essential because they help to ensure that portable wheelchair ramps are used correctly and therefore safely. Compatibility between the ramp, the vehicle, and the wheelchair is essential if they are to be used effectively and safely. Compatibility can only be achieved if the optimal design and combination of features are selected for the model of vehicle used and the abilities of the caregiver. The ease of use and portability of the ramps was influenced by size

and mass and also by the presence of handles, the option for folding, and the inclusion of locking mechanisms.

The portable wheelchair ramps that we evaluated were all based on singlewide platform or channel designs. Overall, the wheelchair users preferred the wide ramps because these could be used with greater confidence and speed and the caregivers preferred the channel ramps because these could be handled more easily.

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