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To cite this article: Ernesto Morales, Sally Lindsay, Geoffrey Edwards, Lori Howell, Claude Vincent, Nicole Yantzi & Véronique Gauthier (2018) Addressing challenges for youths with mobility devices in winter conditions, *Disability and Rehabilitation*, 40:1, 21-27, DOI: [10.1080/09638288.2016.1239768](https://doi.org/10.1080/09638288.2016.1239768)

To link to this article: <https://doi.org/10.1080/09638288.2016.1239768>



Published online: 07 Dec 2016.



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RESEARCH PAPER

Addressing challenges for youths with mobility devices in winter conditions

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ABSTRACT

Purpose: Winter-related research about the experience of navigating in the urban context has mostly focused on the elderly population with physical disabilities. The aim of this project was to explore potential design solutions to enhance young people's mobility devices and the built environment to improve accessibility and participation in winter.

Methods: A multi-method qualitative design process included the following steps: (1) in-depth interviews; (2) photo elicitation; (3) individual co-design sessions; and (4) group co-design sessions (i.e., focus group). The participants were 13 youths (nine males and four females), aged 12–21, who used a wheelchair (12 power chair users and one manual wheelchair), for some with their parents, others without their parents, according to the parents' willingness to participate or not in the study ($n = 13$). The first two authors conducted group co-design sessions with mechanical engineers and therapists/clinicians in two Canadian cities to discuss the feasibility of the designs.

Results (findings): The youths and their parents reported different winter-related challenges and proposed specific design solutions to enhance their participation and inclusion in winter activities. Seven of these designs were presented at two group co-design sessions of therapists/clinicians and engineers. Two designs were found to be feasible: (1) a traction device for wheelchairs in snow and (2) a mat made of rollers to clean snow and dirt from tires. The results of this research highlight the frustrations and challenges youths who use wheelchairs encounter in winter and a need for new solutions to ensure greater accessibility in winter.

Conclusions: Therapists/clinicians and designers should address winter-related accessibility problems in areas with abundant snow.

ARTICLE HISTORY

Received 10 September 2015

Revised 14 September 2016

Accepted 19 September 2016

KEYWORDS

Hibernal accessibility; difficulties; motor disabilities; accessibility; wheelchair improvements; environmental barriers; co-design methodology

► IMPLICATIONS FOR REHABILITATION

- Several studies show that current urban contexts do not necessarily respond accurately to the needs of individuals with limited mobility.
- Winter-related research about the experience of navigating in the urban context is limited and has mostly focused on the elderly population with physical disabilities.
- Our results clearly show that youth who use mobility devices want to be able to get around in the snow, wander outdoors, play and enjoy social participation in activities with their peers and friends.
- Our findings provide a starting point for the development of additional studies to seek a better understanding of the person–environment interaction in winter conditions, with tangible results in the form of better design solutions.
- Clinicians and designers must address such issues in northern countries and areas where snow is abundant.

Introduction

Several studies have shown that current urban contexts do not respond well to the needs of individuals with limited mobility. Heavy traffic, poor street lighting, difficulty accessing services, and noise can all influence decisions about whether to go outside for individuals with motor disabilities.[1,2] Well-lit streets, places of leisure,[3] parks, open spaces, the perception of a safe neighborhood,[4,5] ramps, curb cuts, automatic doors, wider doors, elevators and smooth surfaces on pavements and sidewalks promote mobility in individuals with (and without) disabilities.[6]

In addition to the built environment, winter conditions also have an impact on individuals' mobility.[7] Several elements significantly influence mobility in the built environment in winter, including long periods with the temperature below freezing, snow, and decreased sun exposure.[8,9] Moreover, the increased risk of falling, reduced thermal comfort,[10] worsening of chronic diseases, the risk of hypothermia,[11] and the possibility of frost-bite due to poor circulation have a significant impact as well. Winter can affect an individual's overall well-being. Indeed, in the study by Fischer and Van de Vliert,[12] a cold climate was shown

to have an impact on people's well-being since it increases the risk of health problems, anxiety, and depression due to increased physical demands, and stress. It seems clear that winter represents a real challenge for people with mobility limitations.

Canadian winters are known to be both beautiful and extremely long and cold. However, Canadians tend to pride themselves on being tough enough to not only survive but also enjoy the months of cold weather.[13] This is reflected in winter carnivals and festivals with rides for children and adults, ice-sculpture contests, concerts and even hotels made out of ice. While winter, with its winter sports and snowball fights, can be fun and exciting for able-bodied Canadian children, for the over 200 000 children with disabilities,[14] it may have different connotations. So far, winter-related research about the experiences of navigating in the urban context has mostly focused on elderly people with physical disabilities; it is time to pay attention to young people too.

Objective

To explore potential design solutions to enhance young people's mobility devices and the built environment to improve accessibility and participation in winter.

Methods

This article presents a portion of a larger study, as the results of steps 1 and 2 (interviews and photo elicitation) have already been published as Lindsay et al. [8] The steps in this project involved: (1) in-depth interviews (with teenagers or young adults, and in some cases with their parents); (2) photo elicitation (of youths' experiences of winter); (3) individual co-design sessions (with youths, and in some cases with the parents); and (4) group co-design sessions (i.e., focus group with professionals). This is a multi-method qualitative design including in-depth interviews and co-design sessions, following the method described by Morales et al. [15] This paper reports on the co-design sessions that drew on participants' experiences with the aim of exploring possible design solutions to improve accessibility and inclusion.[16] Nevertheless, all four steps are described in further detail below. The inclusion criteria of the participants were: (1) youths with mobility problems that required the daily use of a manual or power wheelchair (their diagnoses included cerebral palsy, spina bifida, spinal cord injury, muscular dystrophy, and amputation); (2) aged 12–21; who had (3) at least one year's experience of using a mobility device. In some cases, parents ($n=13$) participated to comment on the youths' idea. Participants were recruited from the database of clients at the Department of Technical Aids at Quebec's Institute of Rehabilitation of Physical Disabilities (L'Institut de réadaptation en déficience physique de Québec – IRDPQ). A researcher contacted potential participants from the IRDPQ's database. The participants were 13 youths (nine males and four females), aged 12–21, who used a wheelchair (12 power chair users and one manual wheelchair), for some with their parents, others without their parents, according to the parents' willingness to participate or not in the study.

The steps in this project included:

1. *In-depth interviews (with the teenager or young adult, and in some cases with the parents)*: The young participants were met at their homes during the winter months (December–March), and the project was explained to them. The open-ended questions in the interview focused on challenges, barriers, opportunities, and facilitators to going

outdoors during winter (i.e., accessibility, inclusion and ideas to improve their devices for winter).

In addition, a trained member of the research team gave the participants an information package and instructions on how to document their experiences using a camera and a structured journal that included the date and space to enter what activities they did in the morning and afternoon.[8]

2. *Photo elicitation (with the teenager or young adult, and in some cases with the parents)*: Over a one-week period, participants were asked to record their winter-related experiences in photos. This included taking at least two photos per day of their activities, especially on days when the weather was bad. They were also asked to record the date, time and a brief photo caption that would represent or document their experiences of winter. This method is a well-established tool [17–19] used to reflect specific realities, in this case of youths with disabilities. Photos were uploaded to a secure, password-protected site for analysis. The results of the interviews and photo journal are discussed in further detail by Lindsay et al. [8]
3. *Individual co-design sessions (with the teenager or young adult, and in some cases with the parents)*: The co-design sessions took place one week later, after the first interview and after the researcher had time to review the photographs and the journal.

This research was based on a user-centered design approach,[20] which incorporates participants' views and sees them as "partners" who provide expertise and participate in the early phases of the design process.[21] Co-design methodologies have been successfully used in many different domains and with various populations, including youths with disabilities.[15,22,23] For our study, during the co-design sessions, the participants were asked to describe ideas concerning how to improve their own mobility devices during winter; the first author (a designer able to create drawings for validation) drew their suggestions on paper in front of them to validate their ideas. The participants were the teenagers and young adults; in some cases, the parents would also make some suggestions to help make their children's ideas clearer or add some features to the idea based on their "parental perspective." This process generated new ideas and *graphic data*, [15] which were collected by the researcher. The graphic data comprise a set of ideas drawn by the main researcher and validated by the participants. The principle is based on the idea that everybody has high creative potential and aims to explore participants' ideas of how to improve their own situation. Each session lasted between 90 and 120 min.

4. *Group co-design sessions (focus group with professionals)*: Two group co-design sessions were conducted by the first author in two Canadian cities. In assembling the members for the group co-design sessions, a special effort was made to find participants with different professions related to disability, to the accessibility of the built environment, and to young people. We presented the ideas generated earlier by the youths (i.e., both their experiences and the graphic data) to a purposive sample of engineers and therapists/clinicians, including occupational therapists with at least one year of experience working with youths who use a mobility device and engineers who had experience designing mobility devices (see Table 1). This allowed key stakeholders to critique, enrich, and validate the design solutions proposed by the youths. All the professionals were recruited through two rehabilitation institutions in Quebec City and Toronto. Questions were asked about the feasibility and safety of each

design and other possible modifications. New design solutions were generated based on these discussions, incorporating the comments of participants in both group co-design sessions. Ethics committees from both institutions in Toronto and Québec City approved the project.

Data analysis: The data from all the individual co-design sessions and both group co-design sessions were recorded digitally and transcribed as text; in addition, there were “graphic data” obtained from the drawings produced at the sessions (group and individual). Using NVIVO, a qualitative analysis software package,[24] two members of the research team independently read through all the transcripts and noted the emerging themes with an open coding procedure. A coding framework was then developed based on the ideas expressed by the participants; feasibility, difficulties, and problem-solving characteristics were some of the main themes. Two additional investigators read a sample of the transcripts to verify the coding framework. This validation process was developed to ensure that the themes encompassed all the ideas expressed by participants.[25] For example, when open questions were asked such as “What would you do to your wheelchair to improve accessibility in winter conditions?” a frequent suggestion was to have a traction device. More detailed explanations were then requested and the feasibility, difficulties and problem-solving characteristics were identified

in a text developed in tandem with the graphic data (drawings). Additional themes emerged with each solution, such as special requirements for the implementation (i.e., special technical features) or special requirements for applying the idea (i.e., special clothing). The data analyses for the group co-design sessions with professionals were similar to those applied to the individual co-design sessions involving youths and their parents; however, special attention was paid to the feasibility aspect in the group co-design sessions.

Results (findings)

The young people and their parents generated 12 design solutions. Group consensus was used to choose seven out of the 12 design solutions based on the criteria of feasibility, recurrence and originality. The four co-researchers, one clinician, and one research professional composed the group. For example, one participant suggested installing a plastic roof over all the sidewalks in Québec City, while another thought that a wheelchair with 2-m-diameter wheels would be able to cross any obstacle; these two ideas were not included because they were not feasible. Concerning recurrence, sometimes more than one participant suggested a very similar idea, so only one version was selected. Finally, originality referred to ideas that shed new light on the problem. In fact, all seven ideas presented at the group co-design sessions were considered original. Variations of some of these ideas have already been developed and can be found on the Internet or in the market (e.g., see the MTT-136: <https://www.youtube.com/watch?v=gclwrdeP21s>).

Of the seven ideas presented at the co-design group sessions, two solutions were considered as the most “feasible and with lots of potential” by a consensus of participants in both group sessions. These are (1) a traction device for wheelchairs in snow and (2) a “mat” made of rollers to clean the snow and dirt from wheelchair tires. These solutions are described below. Additional findings are also provided to give a more comprehensive view of the challenges facing young people who use a wheelchair in winter conditions and their related desires. These findings are presented in the section on other improvements suggested by participants.

Traction device for wheelchairs in snow

Several participants proposed a system like the one used in snowmobiles, with skis in place of or in front of the front wheels (some of these suggestions are presented in the graphic data; see Figure 1). To illustrate,

A system related to a snowmobile, that would be interesting too (...) on the same principle as all four wheels, in winter they put a caterpillar with skis (...) without changing the wheels, could put a caterpillar over (...) but two different tracks for each wheel to allow for steering. (Parent of participant #9)

The professionals believed that this idea was feasible, but they raised some issues nonetheless. The traction device was proposed to be controlled either by a steering wheel or by an additional joystick to be attached to the wheelchair, next to the joystick used to control the wheelchair itself (in the case of power chairs). The wheels would be placed on skis; a powered wheelchair would be turned off, as the movement would come from the device. This device was described as harnessing the traction from two pairs of wheels, with each pair being connected via a traction band for snow. The traction device was something that participants in both group co-design sessions agreed was an excellent idea; however, they believed that this solution would be more

Table 1. Composition of the co-design session.

Profession	Clinical experience with youth	Number
Québec		
Occupational therapist	1	3
Kinesiologist	–	1
Cognitive geomatcian	–	1
Psychologist	1	1
Electronics technician	–	1
Sociologist	–	1
Toronto		
Occupational therapist	2	2
Physiotherapist	1	1
Biomedical engineer	2	2
Biomechanical engineer	1	1
Sociologist	1	1

Table 2. Winter themes^a.

	Themes raised by youths with disabilities	Themes mentioned in Québec City	Themes mentioned in Toronto
1. Participation in winter	X	X	X
2. Nonparticipation in winter	X	X	X
3. Physical barriers/obstacles	X	X	X
4. Wheelchair maintenance	X	X	X
5. Wheelchair design for winter	X	X	X
6. Suggestions for improving accessibility	X	X	X
7. Clothing	X	X	–
8. Health	X	X	X
9. Safety	X	X	X
10. Advice to others in the winter	X	X	X

^aThe themes presented below are only the main themes and the subthemes are not listed in this table in order to lighten its content. The following example is provided in order to give readers an idea of the subthemes.

Theme 1, *Participation in winter*, was subdivided as follows.

1. Participation in winter.

1.1 Average time spent outside.

1.1.1 Time outside for youth with disabilities is usually just waiting for the bus or getting to and from vehicles.

1.1.2 Go out about the same amount in summer and winter (different activities).

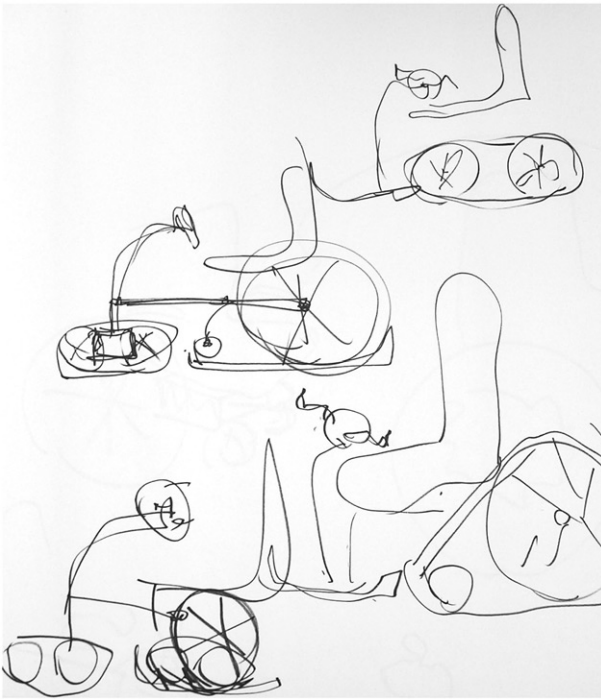


Figure 1. Pulling device.

useful for leisure activities than for everyday urban mobility. All participants agreed that this could improve the quality of life of youths who use a wheelchair. However, the cost of such a solution would have to be accessible for families. For instance, professionals in the group co-design sessions said,

Are there models of wheelchairs with snowmobile-like wheels? Yes, it already exists (...) and they are big! And expensive! And you cannot get them in your car! (...) But I think with a snowmobile-like system there are many advantages (...), but you cannot perform your normal activities with it, like going to public places or on the bus (...) but to participate in leisure activities, yes (...) walking in the woods. (Group co-design session 1) [Boldface indicates the interviewer's questions]

If you think about it, this is like the minimalized version of a snowmobile, cost-wise we have to think about something that people can afford. As low cost as possible. (Group co-design session 2)

Solution for cleaning the snow from a wheelchair

While using a wheelchair in winter, young people often have no choice but to drive where there is salt, gravel, and dirt. The accumulated debris on the wheels causes significant problems when they have to go indoors in places such as rehabilitation centers, hospitals, schools, shopping centers, restaurants, etc. Among the design solutions discussed with the young people, this solution (Figure 2) was thought to be appropriate for large institutions such as rehabilitation centers or hospitals. The idea is that the wheelchair rolls across a series of metal rollers that are warm enough to melt the snow. There would be gaps between the rollers so that the sand and snow could fall into a receptacle. There would have to be an on/off button to start and stop the rollers so that the wheelchair can get onto them and off again. A participant describes it as follows:

It would be like making a carpet roll, like where each wheelchair user who comes over would be rolling their wheelchair on the rollers and it would clean the wheels (...) to install this in places like schools where there are many people with wheelchairs (...) it would follow the same principle as the machines that exist for shoes at the entrances of public buildings. (Parent of participant #10)

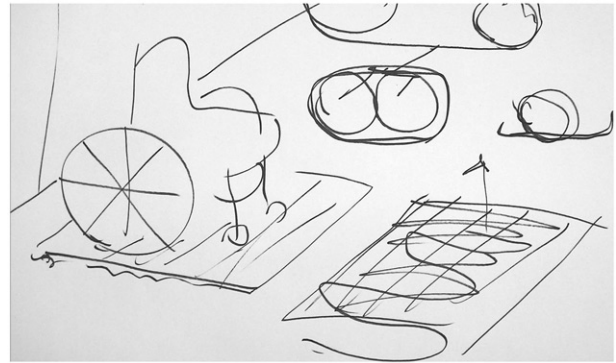


Figure 2. Cleaning the snow from wheelchairs for institutions.

According to the professionals taking part in the group co-design sessions, this design solution could be feasible. Certain issues were raised, however, including technical issues related to constructing the rollers and cost-related issues. These were addressed, to some extent, with the idea that this solution would be implemented in institutions and not necessarily in homes.

Do you think it's a complex idea or not? Should they try this at this school where there are 200 students a day in a wheelchair? It could be a good investment (...) more for Quebec because there is more snow in Quebec than in Toronto. (Group co-design session 1)

Additional findings and other important issues raised by participants related to accessibility during winter conditions

Many youths reported being unable to go outside in all kinds of winter weather. They mentioned, for example, that adapted transportation services are usually cancelled if a snowstorm is forecast.

Does the weather sometimes prevent you from using adapted transportation? Yes, when there is snow, sometimes they just do the clients that require medical (assistance). (Young adult participant #11) Yes, it is canceled much faster now, as soon as they announce a storm. (Parent of participant #11)

Other aspects that were mentioned included some of the obstacles participants face going out, such as poorly plowed and salted sidewalks and roads, blocked curb cuts and snow-covered playgrounds and accessibility ramps for wheelchair users (Figure 3). The explanation of the figure is as follows:

That is the Community Center. When you enter, there is a long sidewalk with a long ramp for wheelchair users that goes up. But it is not cleared of snow in winter. So there is a big ramp, but there is no access because they have not plowed it. In addition, there is a large container that blocks the entrance ramp. (Parent of participant #16)

The freezing and thawing of roads and sidewalks create surface damage that can cause difficulties for young people trying to move around outside with their wheelchairs (powered or manual). It is common for the small front wheels on wheelchairs to get stuck in holes or slots. The entrances of homes and public institutions regularly used by youths who have a wheelchair may also experience significant damage due to temperature changes. For this reason, better maintenance of roads, sidewalks and driveways is crucial.

On the sidewalk, the wheelchair got stuck in a hole, because with the formation of ice and melting of the ice, the pavement ends up cracking. So we fell into this hole and the front wheels were stuck and the rear wheels were lifted high, even though I was holding the wheelchair very tightly. (Parent of participant #10)



Figure 3. Curb cut not cleaned so the young participant cannot use the ramp (Teenage participant 9).

Some public places are not accessible for youths who use a wheelchair. Doors are not always properly adapted for people with a wheelchair (e.g., the doors do not open on the right side, they do not provide a wide enough opening, there are steps that block access to doors or the accessibility button is located too high). Furthermore, in winter the access buttons for automatic doors sometimes freeze. Thus, public places need to be renovated, adding more lifts and automatic doors (with anti-freeze mechanisms for the button) to help people who use a wheelchair to move around in the urban environment. One participant stated that, “Electric doors freeze (...) button is frozen too. This is not directly a problem related to my chair, but it is still a problem” (Young adult participant #8).

Youths who have to use the subway to travel suggested the installation of more visible signs indicating how to get to the elevators that are available in some subway stations.

Even some of the accessible subway stations are really not (...) It is one thing if you are in a chair and you are pushing somebody but she was using a walker (...) that was in [name] Station and it is accessible, technically speaking, but it's not practical. (Young adult participant #5)

In winter, it is also common for pedestrian crosswalk buttons to be inaccessible due to snow accumulation. Hence, the young people suggested improving the accessibility of pedestrian crosswalk buttons. For example,

Sometimes I've noticed they plow up all the snow right where you need to press the button and you've got to climb over a pile of snow to press the button. Yes, that happens a lot. Oftentimes they say that they've plowed the sidewalk and it's not even worth it to try and cross the street. (Young adult participant #3)

Another problem that surfaced was the issue of taking cover from rain, snow, or freezing rain while holding an umbrella and

simultaneously trying to drive the wheelchair. One participant suggested installing plastic roofs over the main sidewalks, during winter only, so that people can get outside and not have to struggle with snow. The participant said,

Having a temporary cover/roof for the sidewalk that would go as far as the curb cut during winter (...) OK, so it could be much larger than any other roof and it would cover a large area of pavement at specific locations, such as malls. Yes, it would be crazy! (Young adult participant #8)

This solution was not adopted by either of the two group co-design sessions, as it was considered impractical to cover sidewalks for any distance.

Given the difficulty of moving around in the snow during winter, most youths focused on proposing solutions to improve their wheelchairs. Among the solutions for powered chairs, some participants suggested preventing the controls of the wheelchair from getting wet from water or snow. One suggested creating water-resistant (or waterproof) controls. Water and snow can severely damage a chair's electronic control system, and so it was recommended that the controls remain dry at all times.

I would say put a bag over the controls so they don't get wet. Do you find that you're always thinking about the power at the back or other parts of it getting wet or icy? Well, when I got the wheelchair, they pretty much said everything should be fine except for the controls (...) I guess you could probably make the controls waterproof but that would cost a lot of money. (Teenage participant #1)

Snow accumulation at roadsides, on sidewalks, and alongside vehicles parked on the streets can make it more difficult for young people using a wheelchair to move around outside during the winter season. Some participants would like to have more customized programming for their power chairs to meet the unique demands of a winter climate.

I have a program for inside, like for in the halls at school. I have another program which is just more for outside, and then I have a program which is for heavy-duty ice, to get out of something, and then I have a last program for the classroom. It will start right away (...) I pretty much use that all the time in the winter. Did your wheelchair come already programmed with those settings or did someone program them for you? Someone came in and programmed it for me. (Teenage participant #1)

In winter, the lack of light in the evening affects wheelchair users' ability to see obstacles that may affect their safety. Thus, several youths mentioned the idea of attaching lights to wheelchairs so they could see better and be seen in the evening. In addition, some also suggested wearing reflective clothing to make themselves more visible to vehicle drivers or cyclists. These measures could increase safety and reduce the risk of accidents on winter nights.

When I first my power chair, I did request lights for such conditions as these or traveling at night. Unfortunately, I was refused for this and so what I've had to do is use reflective strips. I have a bunch of them all over my wheelchair. I usually wear reflective clothing as well (...) that was a funding issue (...) that would be something that I would like to see changed. I don't know what the results of this study are going to be, but as for getting user experience, I would say things like lights and other protective mechanisms are really important. As you said, it's like driving a car without lights. (Young adult participant #3)

The distribution of sand and salt was a topic participants often mentioned. Before young people using a wheelchair go outside their homes in winter, their parents need to regularly sand or salt their entrance. Salt or sand is effective for several minutes after its application; however, this operation needs to be repeated after

about 20 min to be effective for wheelchair users (Parent of participant #11). Two participants suggested having a salt distributor attached to their wheelchairs. In that way, young people using a wheelchair could be independent of their parents and might be able to contribute to reducing the slipperiness of their entrance and sidewalk. For example,

Once you put salt and sand on, two minutes later it is effective. So it might be a good idea to install a device below the seat to distribute sand and salt. Sometimes we are not there, or if she wants to leave the house would be practical (...) and yes, it does not take much, a small salt dispenser! (Parent of participant #11)

The weather conditions in winter often affect the length of time it takes for youths who use a wheelchair to leave the house. When they use adapted transportation, sometimes the vehicle is some distance from their home (e.g., there may be a garage or driveway to cross). The accumulation of snow makes it difficult to get to and from the transportation stop. Adapted transport vehicles have lifts and platforms for the client that are designed to work on flat surfaces, which are hard to find in winter. As a result, several young people suggested improvements to transfer devices for adapted vehicles. For example,

*Adapted cars have these lifts and platforms made for a perfect angle, but that angle is not perfect. **OK, this is something that happens mainly in the winter because of the snow?** Yes, but it sometimes happens in the summer with pebbles (Participant #11). **Is it very difficult to push the chair?** The powered wheelchair is quite heavy, but the manual is not difficult. (Parent of participant #11)*

The cold can cause discomfort in the hands and feet, frostbite and respiratory problems. Moreover, the difficulty of driving a wheelchair while wearing heavy layers of clothing was also mentioned by all participants (with manual or power wheelchairs). They have significant problems wearing mittens while driving the wheelchair, but without mittens, they often get frostbite. Furthermore, heavy winter coats can restrict wheelchair users' movements. Most participants talked about creating more suitable boots, pants and gloves for winter. All these garments would have to be easier to put on, thinner and more resistant to cold weather. One participant describes,

You cannot put winter boots on because of the orthotic braces and his feet freeze (...) In terms of clothing, there are probably many things to do. Mittens for children "unzip" to the end, but the ones for adults don't do that. So what they came up with for children, they should do the same for youths with disabilities concerning mittens and boots (...) it is already invented for children, all they have to do is to adapt it for adults. (Parent of participant #10)

Discussion

Our results are consistent with other publications concerning the significant diminishment of the individuals' social participation in winter conditions.[8,26,27] During the summer, many roads and sidewalks are wheelchair-accessible and temperatures allow individuals using mobility aids to stay outside longer. They do not need to wear bulky winter clothes, which affect how they sit in their chairs and access their controls or wheels for propulsion. In addition, they are more autonomous because they can go outside without necessarily being dependent on adapted transportation or on their parents.[8] In winter, however, the story is very different.

The results also show the difficulties that youths with disabilities encounter during winter conditions, which seem to be, to some extent, similar to the challenges faced by elderly people.[8,28–30] However, the fundamental difference between youths and seniors might be the young people's desire to

get outside of their homes in winter, in order to take part in the social/leisure activities that are so important for self-construction.[8,28–30] It seems that, even though winter conditions play such an intrinsic role in the lives of Canadians, the implications for society and in particular for more vulnerable populations such as wheelchair users, are generally not adequately addressed. The problem is that there are not many studies or design solutions addressing this issue, particularly for children with motor disabilities, so therapists and clinicians are unable to respond adequately in their practice. Therapists and clinicians should look for signs of low participation and/or challenges that young people who use a wheelchair encounter during the winter and seek solutions or connect these youths with appropriate community partners to help overcome barriers and promote winter activities for them.

Of the 12 different design solutions proposed by the youths to make spaces more accessible or improve wheelchair designs, two were deemed feasible by the professionals at the group co-design sessions. Being able to go outside, by using a traction device, and getting back indoors without creating a mess, by using a roller mat, represent two solutions that could substantially improve these young people's social participation, allowing them to go outside, play, move around, and have fun.

The limitations of this study include its limited group co-design sessions (only two cities) and restriction to a specific age group (12–21) who participated in the individual sessions. Further studies should explore more geographical areas and include a broader range of professionals with different experiences of working with youths with mobility issues (e.g., kindergarten teachers, school teachers) and different types of mobility devices. The number of participants was also small; however, in a qualitative study with a co-design methodology, a smaller number of participants is recommended due to the duration of the individual co-design sessions (i.e., where sessions are long).[15]

Conclusions

Our study addresses two weather-related mobility issues identified in the literature by asking youths, parents, therapists/clinicians, designers, and engineers to identify potential design solutions (i.e., person–environment interaction in winter and development of design solutions).[26–30] Our findings provide a starting point for the development of additional studies that seek a better understanding of the person–environment interaction, with tangible results in the form of better design solutions. The next crucial step is the development of prototypes and tests to move these ideas forward. The traction device for wheelchairs is currently under discussion with a Quebec-based company that sells and develops a similar machine that people without disabilities use to pull sleighs. The researchers hope that the other co-design solutions (winter tires and roller mat) will also be realized and help to improve the winter participation of young people who use wheelchairs.

Designers, therapists/clinicians, and industry need to work together to find solutions to improve the social participation of young people who use mobility devices, as they struggle every day in winter conditions. Once this is achieved and more venues become accessible to these youths, the idea of "winter management" could be incorporated into the assessment process – thinking about where a client is located, identifying the barriers that these conditions pose, and then looking at solutions integrated into a mobility device prescription.

Acknowledgements

We would like to thank Kelsey Lecoure, Effie Biliris, and Veronique Gauthier for their research assistance. We also thank the participants who took part in this study.

Disclosure statement

The authors report no conflicts of interest.

Funding

Funding for this research was provided by a Bloorview Research Institute and CIRRIIS catalyst grant.

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