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The Most Important Assistive Devices for Persons with Spinal Cord Injury in Switzerland: A Cross-Sectional Study

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Abstract: Persons with spinal cord injury (SCI) rely significantly on the use of assistive devices (ADs) to increase independence and enhance participation. This study aimed to determine the most important ADs for persons with SCI living in Switzerland and to identify design features of potentially novel ADs greatly facilitating persons with SCI in performing the tasks of daily life. Descriptive statistics were used to analyze cross-sectional data (N = 1294 participants) from the Swiss Spinal Cord Injury Cohort Study 2017. Open-ended questions regarding the importance of ADs and desirable novel ADs were manually coded and assigned to categories. The results showed that the most important ADs for persons with SCI were a manual wheelchair (61%), an adapted car (46%), and a wheelchair tractor (20%). The importance of ADs varied with gender, age, and SCI severity. While none of the participants indicated a desire for a completely novel AD, over one-fifth described specific design features of novel ADs or adaptions of existing ADs, which were most often related to facilitating transfer (12%), walking support (10%), and facilitating access (9%). These findings have implications for the design and development of ADs to better meet the needs of persons with SCI, improve their quality of life, and promote their independence and participation in daily activities.

Keywords: assistive devices; assistive products; spinal cord injury; design of assistive devices; perspectives of individuals with spinal cord injury; needs

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1. Introduction

Spinal cord injuries (SCI) have a tremendous impact on individuals' lives [1]. The loss of sensation and mobility can affect the ability to participate in activities of daily living that are typical of an independent and productive lifestyle [2]. Therefore, individuals with SCI significantly rely on assistive devices (ADs) [3] to increase their independence and enhance their participation [4].

ADs are defined as "any item, piece of equipment, or product system, whether acquired commercially, modified, or customized, that is used to increase, maintain, or improve functional capabilities of individuals with disabilities" [5]. While ADs cannot improve an individual's capacity, they can expand the range of activities a person can perform by improving their performance [6].

Switzerland has a comprehensive system for the provision of ADs [7]. Financial coverage is available through a complex network of social insurance schemes, including accident, old-age, invalidity, health, and military insurance [8]. The responsibility of the respective institution is regulated by federal law and based on various factors, such as the SCI etiology and the age, occupation, and degree of employment of the individuals with SCI [9].

Research on ADs and persons with SCI has primarily focused on the provision, availability, and frequency of use of existing ADs [7,10–12]. The findings show that the highest provision in terms of mobility devices in Switzerland is for adapted vehicles and manual

wheelchairs (wheelchairs designed to be propelled by the user, by pushing with both hands on the hand rims of the wheels) [7]. Most ADs such as manual wheelchairs are used daily, and three out of four persons with SCI in Switzerland have at least one home adaptation, with wheelchair-accessible showers being the most common [10]. Individuals with tetraplegia commonly use ADs such as adapted cutlery, type supports, environmental control systems, and writing orthosis to compensate for impaired hand function [11]. Although persons with SCI in Switzerland seldom report a lack of mobility devices, there is an unmet need for other ADs, such as arm braces, power wheelchairs (wheelchairs powered by electricity), accessible kitchen worktops, and adjustable kitchen cabinets [10,11].

For ADs to be effective, they must meet the preferences and needs of the users [13]. Therefore, it is crucial to assess the perspectives of persons with SCI as the main users of ADs [6] and to determine whether they use a particular device because it is genuinely useful in completing daily tasks or simply because no other suitable devices are available [4,14]. Consequently, involving persons with SCI in the design, development, and evaluation of ADs is essential.

Currently, there is limited information on how useful ADs are from a user's perspective and whether there is a need for novel devices that are not yet commercially available [6]. This study aims to address this knowledge gap by exploring the perspectives of persons with SCI regarding existing ADs and the potential development of novel ADs. Specifically, this study aims to (1) determine the most important ADs for persons with SCI in Switzerland and (2) identify design features of novel ADs that would be helpful in performing everyday tasks.

2. Materials and Methods

2.1. Study Design and Sample

Cross-sectional data from the community survey of the Swiss Spinal Cord Injury (SwiSCI) Study conducted from March 2017 to March 2018 were used [15]. SwiSCI is an ongoing nationwide and population-based cohort study that seeks to better understand the quality of life and health of persons with SCI. The study includes individuals diagnosed with traumatic or non-traumatic SCI, aged 16 years or older, living permanently in Switzerland. Excluded from the study were individuals with congenital conditions leading to SCI (such as spina bifida), neurodegenerative disorders (such as multiple sclerosis or amyotrophic lateral sclerosis), and Guillain-Barré syndrome [15,16]. Due to the lack of a central register for persons living with SCI in Switzerland, the study population was established based on the registries of the four Swiss specialized rehabilitation centers (Swiss Paraplegic Centre, REHAB Basel, Clinique Romande de Réadaptation, Balgrist University Hospital) and two SCI support organizations (ParaHelp, Swiss Paraplegic Association) [15,16]. Participants could choose between paper-based or web-based questionnaires and telephone or face-to-face interviews. The questionnaire was provided in three official Swiss languages (German, French, and Italian) [15,16]. The invited source population included 3959 persons, whereby 1294 persons completed the questionnaire (response rate 33%) [15].

2.2. Measures

2.2.1. Most Important Assistive Devices

Specification of important ADs was evaluated by self-report in answer to an open-ended question asking participants to name up to five technical aids (ADs) that are particularly important for them ("Name up to five technical aids that are particularly important for you"). We then coded the open-ended answers and assigned them to ten categories: (1) short-distance mobility device (e.g., manual wheelchair, canes, crutches, orthoses), (2) long-distance mobility device (e.g., adapted car, power wheelchair, wheelchair tractor), (3) home adaptation (e.g., adapted bathroom, care bed, stair lift), (4) transfer equipment (e.g., slide board), (5) sports equipment (e.g., hand bike, sit ski), (6) communication aid (e.g., adapted mouse, type aid), (7) daily activity/self-care tool (e.g., adapted cutlery, bowel

and bladder care), (8) positioning device (e.g., chair, cushion), (9) environmental control device, and (10) medical aid (e.g., electric stimulation).

2.2.2. Novel Assistive Devices

The design features of potentially novel ADs or adaptations of existing ADs were evaluated based on the participants' answers to two open-ended questions.

First, participants were asked which tasks of daily life present problems that could be greatly facilitated in the future by a novel AD ("For which tasks of daily life do you have problems, which could be greatly facilitated in the future by a new type of aid?"). The answers to this question were coded and assigned to 13 categories: (1) walking, (2) transferring alone, (2) moving around, (3) doing housework, (4) preparing meals, (5) home adaptations/access, (6) washing oneself, (7) bladder and bowel management, (8) dressing, (9) lifting and carrying heavy objects, (10) driving, (11) maintaining body position, (12) sports, and (13) other, including problem areas not assigned to any of the other categories.

Second, participants were asked what this novel AD could look like ("What could this tool look like?") (inviting description of design features). The answers to this question were also coded and assigned to nine categories: (1) facilitating transfer, (2) walking support, (3) facilitating access, (4) adapted car, (5) height-adjustable, (6) remote control, (7) stair climbing, (8) lightweight, and (9) other, including design features of ADs not assigned to any of the other categories.

2.2.3. Other Measures

Information on SCI characteristics included self-reported SCI etiology (traumatic, non-traumatic), SCI severity (incomplete paraplegia, complete paraplegia, incomplete tetraplegia, complete tetraplegia), and time since injury in years (grouped based on the guidelines of the International Spinal Cord Society (ISCoS) and evaluated for the SwiSCI community survey [17] into four categories: $\leq$5, 6–15, 16–25, 26+).

Sociodemographic and socioeconomic characteristics included gender, age (at questionnaire, grouped according to the ISCoS guidelines [17] into five categories: 16–30, 31–45, 46–60, 61–75, 76+), living situation (living alone, living with other persons, living in an institution), and work status (engaged in paid work or not).

2.3. Data Analysis

Descriptive statistics were used to analyze participants' characteristics, the ADs most frequently considered important, and the design features of novel ADs. The frequencies of the most important ADs were additionally analyzed stratified by gender, age, living situation, work status, and SCI severity. The design features of novel ADs were analyzed by SCI severity. For all descriptive analyses, the frequencies and percentages were reported. We used Excel to code and categorize the open-ended questions and Stata Version 15.1 (StataCorp, College Station, TX, USA) for statistical analyses.

3. Results

In total, 1294 (33%) of 3958 persons completed the survey. The sample consisted of 374 women (29%) and 920 men (71%) (Table 1). The mean age was 56 ($\pm$14) years, and the mean time since injury was 19 ($\pm$13) years. Overall, 29% of the participants lived alone and roughly half of the participants (48%) held paid jobs. Of the participants, 70% had paraplegia and 30% tetraplegia. Overall, 64% of participants reported incomplete tetraplegia or paraplegia. Traumatic injuries were predominant at 80%.

Table 1. Participant characteristics.

	Total (*N* = 1294) *n* (%)
Gender	1294 (100)
Female	374 (28.9)
Male	920 (71.1)
Age (years)	1294 (100)
16–30	54 (4.2)
31–45	253 (19.6)
46–60	443 (34.2)
61–75	431 (33.3)
76+	113 (8.7)
Living situation	1280 (100)
Living alone	366 (28.6)
Living with others	914 (67.9)
Living in an institution	45 (3.5)
Work status	1221 (100)
In paid employment	586 (48.0)
Not in paid employment	635 (52.0)
SCI severity	1158 (100)
Complete paraplegia	327 (28.2)
Incomplete paraplegia	487 (42.1)
Complete tetraplegia	90 (7.8)
Incomplete tetraplegia	254 (21.9)
SCI etiology	1280 (100)
Traumatic	1027 (80.2)
Non-traumatic	253 (19.8)
Time since injury (years)	1294 (100)
0–5	260 (20.1)
6–15	408 (31.5)
16–25	270 (20.9)
26+	356 (27.5)

SCI, Spinal cord injury.

3.1. Most Important Assistive Devices

Of the 1294 participants, 235 (18%) were excluded from this analysis because of missing values for the respective question, resulting in a subsample of 1059 (82%) participants. Table 2 shows the most frequently mentioned ADs by category. The most important ADs belong to the categories of short-distance mobility device (31%), long-distance mobility device (22%), and home adaptation (17%).

Table 2. Most important assistive devices for persons with SCI, by category.

Assistive Device Category	**Total (*N* = 3761) *n* (%)**
Short-distance mobility device	1159 (30.8)
Long-distance mobility device	840 (22.3)
Home adaptation	619 (16.5)
Transfer equipment	331 (8.8)
Daily activity/self-care tool	312 (8.3)
Sports equipment	207 (5.5)
Communication aid	132 (3.5)
Positioning device	108 (2.9)
Environmental control system	28 (0.7)
Medical aid	25 (0.7)

SCI, Spinal cord injury. Participants could name up to five assistive devices that are particularly important for them.

For the participants, the three most important ADs were the manual wheelchair (61%), the adapted car (46%), and the wheelchair tractor (an electrical add-on drive designed to be coupled to a manual wheelchair to provide powered mobility) (20%). Table 3 presents the most important ADs (individual devices mentioned by at least 100 participants) by gender and age. While men more often mentioned the manual wheelchair (63%), adapted car (49%), adapted toilet (12%), and hand bike (a device that either has its own rigid frame or is attached to a manual wheelchair and has an arm crank propulsion mechanism) (11%) than women, women considered canes (17%) and the computer (including smartphones, tablets) (11%) as more important than men. Older persons more frequently named canes and care beds among their most important devices: 29% of participants aged 76 years or older mentioned canes, but only 11% of those aged 31–45 did so. Care beds were also mentioned predominantly by persons aged 76 years or older (24% vs. 11%). In contrast, the hand bike was more often perceived as important by younger and middle-aged groups, with 20% of 31–45-year-olds indicating this device among the most important. The computer was named considerably more often by 16–30-year-olds (29%) than by 61–75-year-olds (10%). In the 76 and older age group, not a single participant listed the computer as particularly important.

Table 3. Most important assistive devices for persons with SCI, by gender and age.

Assistive Device	Gender			Age					
	N	Male *n* (%)	Female *n* (%)	*N*	16–30 *n* (%)	31–45 *n* (%)	46–60 *n* (%)	61–75 *n* (%)	76+ *n* (%)
Manual wheelchair	644	475 (62.8)	169 (55.8)	644	23 (74.2)	138 (78.9)	231 (76.2)	208 (66.9)	44 (51.2)
Adapted car	491	367 (48.5)	124 (40.9)	491	22 (71.0)	112 (64.0)	197 (65.0)	144 (46.3)	16 (18.6)
Wheelchair tractor	215	151 (20.0)	64 (21.1)	215	3 (9.7)	34 (19.4)	71 (23.4)	94 (30.2)	13 (15.1)
Canes	163	112 (14.8)	51 (16.8)	163	1 (3.2)	19 (10.9)	40 (13.2)	78 (25.1)	25 (29.1)
Care bed	160	117 (15.5)	43 (14.2)	160	7 (22.6)	19 (10.9)	50 (16.5)	63 (20.3)	21 (24.4)
Lift	110	80 (10.6)	30 (9.9)	110	5 (16.1)	16 (9.1)	49 (16.2)	32 (10.3)	8 (9.3)
Adapted toilet	106	87 (11.5)	19 (6.3)	106	2 (6.5)	25 (14.3)	45 (14.9)	31 (10.0)	3 (3.5)
Hand bike	103	83 (11.0)	20 (6.6)	101	3 (9.7)	35 (20.0)	33 (10.9)	26 (8.4)	4 (4.7)
Computer	102	68 (9.0)	34 (11.2)	102	9 (29.0)	37 (21.1)	25 (8.3)	31 (10.0)	0 (0.0)

SCI, Spinal cord injury. Only assistive devices that were mentioned by at least 100 participants.

Depending on the living situation, the importance of the computer varies (Table 4): While 31% of the participants living in an institution consider the computer to be particularly important, this is only the case for 10% of those living with others and 5% of those living alone. At 58%, employed participants were more likely to mention an adapted car than those who were not employed (36%). Moreover, 14% of the employed participants mentioned a lift and 12% the computer, compared to 8% and 7% of the non-employed, respectively.

With respect to SCI severity (Table 5), the manual wheelchair was more frequently reported among the most important ADs by persons with complete paraplegia (85%) than by persons with incomplete paraplegia (46%), complete tetraplegia (61%), and incomplete tetraplegia (51%). Of persons with complete tetraplegia, 39% considered the care bed as most important, compared with only 12% of persons with complete paraplegia. The computer was more frequently considered important by persons with complete tetraplegia (29%) and less so by persons with complete paraplegia (6%).

Table 4. Most important assistive devices for persons with SCI, by living situation and work status.

Assistive Device	Living Situation				Work Status		
	N	Alone *n* (%)	With Others *n* (%)	Institution *n* (%)	*N*	Not in Paid Employment *n* (%)	In Paid Employment *n* (%)
Manual wheelchair	637	187 (64.7)	432 (60.0)	18 (46.2)	615	324 (60.1)	291 (61.3)
Adapted car	486	137 (47.4)	347 (48.2)	2 (5.1)	469	193 (35.8)	276 (58.1)
Wheelchair tractor	213	51 (17.6)	156 (21.7)	6 (15.4)	204	126 (23.4)	78 (16.4)
Canes	161	36 (12.5)	122 (16.9)	3 (7.7)	154	100 (18.6)	54 (11.4)
Care bed	158	47 (16.3)	101 (14.0)	10 (25.6)	150	106 (19.7)	44 (9.3)
Lift	109	27 (9.3)	76 (10.6)	6 (15.4)	106	42 (7.8)	64 (13.5)
Adapted toilet	106	39 (13.5)	66 (9.2)	1 (2.6)	104	49 (9.1)	55 (11.6)
Hand bike	103	21 (7.3)	81 (11.3)	1 (2.6)	101	35 (6.5)	66 (13.9)
Computer	101	14 (4.8)	75 (10.4)	12 (30.8)	98	39 (7.2)	59 (12.4)

SCI, Spinal cord injury. Only assistive devices that were mentioned by at least 100 participants.

Table 5. Most important assistive devices for persons with SCI, by SCI severity.

Assistive Device	SCI Severity				
	N	Complete Paraplegia *n* (%)	Incomplete Paraplegia *n* (%)	Complete Tetraplegia *n* (%)	Incomplete Tetraplegia *n* (%)
Manual wheelchair	579	259 (85.2)	174 (46.4)	52 (61.2)	94 (51.4)
Adapted car	448	202 (66.4)	134 (35.7)	42 (49.4)	70 (38.3)
Wheelchair tractor	194	86 (28.3)	54 (14.4)	22 (25.9)	32 (17.5)
Canes	142	6 (2.0)	101 (26.9)	1 (1.2)	34 (18.6)
Care bed	160	37 (12.2)	34 (9.1)	33 (38.8)	37 (20.2)
Lift	99	40 (13.2)	27 (7.2)	13 (15.3)	19 (10.4)
Adapted toilet	98	60 (19.7)	15 (4.0)	8 (9.4)	15 (8.2)
Hand bike	97	49 (16.1)	32 (8.5)	8 (9.4)	8 (4.4)
Computer	88	19 (6.3)	15 (4.0)	25 (29.4)	29 (15.8)

SCI, Spinal cord injury. Only assistive devices that were mentioned by at least 100 participants.

3.2. Design Features of Assistive Devices

Of the 1294 participants, 438 (34%) were included since they answered the open-ended question regarding describing a problem they have completing daily tasks that could be greatly facilitated by a potentially novel AD or by adapting an existing AD. The most reported problems in daily activities were related to walking (19%), transferring alone (13%), and moving around (9%) (Table 6).

The open-ended question related to potentially novel ADs was answered by 271 (21%) of 1294 participants. None of the participants described a completely novel AD. However, the study participants described specific design features of potentially novel ADs or adaptations of existing ADs. Table 7 presents the design features categorized in total and by SCI severity. The most mentioned design features relate to facilitating transfer (12%), walking support (10%), and facilitating access (9%). Regarding SCI severity, persons with complete and incomplete paraplegia most frequently mentioned design features relating to facilitating transfer (15% and 13%), while persons with incomplete tetraplegia named the adapted car (10%), and persons with complete tetraplegia listed facilitating access (19%) most often.

Table 6. Problem areas in daily activities.

Daily Activity	Total (N = 438) n (%)
Walking	85 (19.4)
Transferring alone	55 (12.6)
Moving around	41 (9.4)
Doing housework	39 (8.9)
Bladder and bowel management	36 (8.2)
Preparing meals	35 (8.0)
Home adaptations/access	33 (7.5)
Washing oneself	28 (6.4)
Dressing	16 (3.7)
Lifting and carrying heavy objects	16 (3.7)
Driving	13 (3.0)
Maintaining body position	12 (2.7)
Sports	11 (2.5)
Other	70 (16.0)

Categories sum up to more than 100% because multiple responses were permitted.

Table 7. Categories of design features of assistive devices, by SCI severity.

Design Features	SCI Severity				
	Total (N = 271) n (%)	Complete Paraplegia (N = 87) n (%)	Incomplete Paraplegia (N = 82) n (%)	Complete Tetraplegia (N = 26) n (%)	Incomplete Tetraplegia (N = 49) n (%)
Facilitate transfer	32 (11.8)	13 (14.9)	11 (13.4)	4 (15.4)	2 (4.1)
Walking support	26 (9.6)	12 (13.8)	7 (8.5)	1 (3.9)	3 (6.1)
Facilitate access	23 (8.5)	6 (6.9)	7 (8.5)	5 (19.2)	1 (2.0)
Adapted car	12 (4.4)	2 (2.3)	2 (2.4)	2 (7.7)	5 (10.2)
Remote control	12 (4.4)	3 (3.5)	6 (7.3)	1 (3.9)	1 (2.0)
Height-adjustable [a]	11 (4.1)	9 (10.3)	2 (2.4)	0 (0.0)	0 (0.0)
Stair-climbing	11 (4.1)	6 (6.9)	1 (1.2)	1 (3.9)	2 (4.1)
Lightweight [b]	10 (3.7)	3 (3.5)	5 (6.1)	0 (0.0)	1 (2.0)
Other	134 (49.5)	33 (37.9)	41 (50.0)	12 (46.2)	34 (69.4)

SCI, Spinal cord injury. [a] This term typically encompasses a range of devices that can be adjusted in height to accommodate the specific needs and preferences of the user (e.g., desks or workstations, countertops, beds). [b] Devices specifically designed to be lightweight, typically made of materials like aluminum or carbon fiber (e.g., lightweight wheelchairs, transfer aids, orthoses).

4. Discussion

This study showed that the most important ADs for persons with SCI living in Switzerland are the manual wheelchair, the adapted car, and the wheelchair tractor (an electrical add-on drive designed to be coupled to a manual wheelchair to provide powered mobility). Although none of the respondents described a completely novel AD, about one-fifth of the participants outlined design features of potentially novel ADs or adaptations of existing ADs. The most frequently mentioned design features were related to facilitating transfer, walking support, and facilitating access.

The importance of manual wheelchairs and adapted cars to persons with SCI in Switzerland has been established in prior research. For example, Florio et al. [7] investigated the provision, use, and unmet needs regarding ADs for personal mobility in the Swiss population with SCI and found that 70% of respondents used manual wheelchairs and nearly 80% used adapted vehicles. Biering-Sørensen et al. [3] reported that roughly half of the persons with SCI in Denmark owned an adapted car, and Harrison et al. [18] indicated that 27% of persons with SCI in Southeastern Michigan had their own vehicle. However,

the latter two studies were conducted over 20 years ago, and the findings may be outdated due to changes in infrastructures or provision systems for ADs.

Our study revealed that the importance of ADs varied based on sociodemographic characteristics and SCI severity. In terms of age, we found that individuals aged 61 years and older most frequently mentioned canes and care beds as the most important ADs, while younger individuals most frequently pointed out the hand bike and the computer. This finding is in line with previous research indicating that younger persons with SCI, and in the general population, are typically more active than older individuals [19,20] and that old age is an indicator of lower levels of use of sports devices such as the hand bike [7]. Regarding the use of computers, a study by Davenport et al. [21], which focused on adults with mobility impairments in the U.S., found that smart technology interventions (e.g., remote control voice/touchscreen, household automation) are still not widely accepted by older adults with mobility impairments.

In terms of gender, men considered the manual wheelchair, adapted car, and hand bike more important than women. The differences regarding the hand bike may be due to differences in activity levels. Well-documented activity trends in both the general population and in people with physical disabilities indicate that men generally report higher activity levels than women [19,20]. However, previous studies investigating the provision of ADs in Switzerland found no significant differences between genders [7]. To gain a deeper understanding of the impact of gender on preferences and needs for ADs, further research is warranted. Specifically, comprehensive investigations are needed to explore the underlying factors that contribute to the varying priorities between men and women with SCI. This research could involve examining additional variables such as lifestyle, societal factors, and individual experiences related to the use of ADs.

The higher importance of the adapted car among men may be related more to work status than gender, as men are more likely to be in paid employment than women in the SCI population [22–24]. The adapted car might reflect the high importance of this AD for employment, i.e., the persons' need for frequent transportation to work in the absence of public transport. Our findings on work status supported this assumption, with 58% of participants in paid employment considering the adapted car as the most important AD, compared to 36% of those not in paid employment. Moreover, those in paid employment more frequently mentioned the lift and the computer, compared to those who were not, likely due to their regular involvement in activities related to the work environment, such as using elevators and working on computers.

We observed that the importance of ADs was dependent on the severity of SCI. Individuals with complete paraplegia considered the manual wheelchair as one of the most important ADs, while those with incomplete paraplegia mentioned canes more frequently. These findings are consistent with Florio et al. [7], who found that manual wheelchairs were primarily used by persons with complete paraplegia, and walking aids such as crutches, walking frames, and leg braces were mainly used by those with an incomplete lesion. Additionally, we found that persons with complete tetraplegia considered the computer as the most important AD, reflecting the importance of advanced technology and the wide range of electronic devices that assist persons with tetraplegia, such as eye-tracking [25], an adapted keyboard, speech-recognition software [26], and screen readers [27]. In their survey involving 15 veterans with SCI, Collinger et al. [4] found that the most important design characteristic for new technologies such as brain–computer interfaces was the capability for independent operation, closely followed by non-invasiveness.

While none of the participants described a completely novel AD, a significant number of them suggested design features of novel ADs or adaptations of existing ADs (e.g., facilitating access or transfer, support for walking, remote control, height-adjustable) that would need further improvement to meet their needs. Our findings are consistent with those of Hertig-Godeschalk et al. [10], who also identified unmet needs for ADs among persons with SCI living in Switzerland, such as adjustable kitchen cabinets and worktops. Similarly, a study conducted among veterans and other assistive technology

users in the U.S. [28] highlighted the need for improved technology and identified key areas for future research and development. These areas encompass advanced wheelchair design (e.g., lightweight, foldable), smart device applications (e.g., environmental control), human–machine interfaces (e.g., brain–computer interfaces), and assistive robotics and intelligent systems [28]. Furthermore, a recent narrative review of reviews [29] revealed opportunities for the technological advancement of assistive technologies, including neuroprostheses, orthotic devices, hybrid systems, and robots. In the specific domain of assistive robotics, Wolff et al. [30] investigated the perspectives of wheelchair users on exoskeleton technology, shedding light on the necessary steps to integrate exoskeletons as mainstream mobility devices. Their findings emphasize the importance of further research and development to enhance exoskeletons in terms of affordability, comfort, safety, and ease of use, ultimately aligning with stakeholder goals. Similarly, Lajeunesse et al. [31] found skepticism regarding the performance of powered exoskeletons for mobility among persons with SCI, indicating the need for ongoing scrutiny and improvement in this area.

Our results emphasize that ADs that greatly facilitate daily activities and participation for persons with SCI already exist. However, what may be lacking is access to these devices and adaptation of the technology to the individual needs of the person. To ensure effective innovation of new ADs, it is crucial to consider the voices of consumers, as emphasized in a systematic review on research and development priorities for mobility assistive technology [32]. Additionally, Alqahtani et al. [32] emphasize the significance of considering various factors such as the context of use, the tasks to be accomplished, the environment in which activities will be performed, real needs and priorities, economic considerations, religious and psychological factors, climate conditions, available technology, materials and resources, and cultural diversity [32]. By incorporating these multifaceted considerations, AD engineers can create solutions that are tailored to meet the diverse and nuanced requirements of users.

Limitations

This study has several limitations. First, the cross-sectional study design restricted the investigation of changes in the importance of ADs over time. Additionally, the findings regarding age could also be cohort effects. Furthermore, as the data are from the SwisSCI survey conducted in 2017, it is possible that the needs for ADs in individuals with SCI and technologies have since evolved.

The practical applicability of our research findings was impacted by various limitations. Low response rates in the questions related to novel ADs limited our understanding of study participants' perspectives. Additionally, the limited descriptions provided by the study participants hindered our ability to offer specific examples or detailed descriptions of design features of novel ADs or adaptions of existing ADs, thus limiting actionable recommendations for practitioners.

Another limitation was the absence of consideration for cost, accessibility, technological requirements, and regulatory factors, which can significantly influence the realization and integration of novel ADs. Unfortunately, the SwiSCI survey questionnaire did not address these aspects, constraining our investigation.

To enhance the practical applicability of our findings, further research is necessary. A comprehensive understanding of novel ADs can be achieved by adopting a mixed-method approach encompassing surveys, interviews, and focus groups. Moreover, to improve the response rate, the inclusion of mobile applications or interactive online platforms, alongside paper-based and web-based questionnaires, as well as face-to-face and telephone interviews, should be considered in data collection methods.

Additionally, relying on self-reported data poses a potential limitation in terms of validity. Self-reported data may be subject to biases and inaccuracies, such as recall bias and social desirability bias. Caution should be exercised when interpreting our results, and alternative data collection methods or objective measures, such as cross-referencing with

medical records or conducting follow-up interviews, could be considered in future surveys to enhance the reliability of findings.

Finally, the possibility of non-response bias exists, as individuals with the most limited hand function and highest need for ADs may have been less likely to participate in the survey. However, the option of a telephone interview was offered to participants to address this issue. Additionally, an analysis of the total SwiSCI community study sample found no significant difference in the probability of survey participation between individuals with tetraplegia and those with paraplegia [33].

5. Conclusions

The current study was the first evaluating the importance of ADs and design features of potentially novel ADs or adaptations of existing ADs to persons with SCI living in Switzerland. The findings showed that the manual wheelchair and adapted car were the most important ADs and that importance varies according to sociodemographic characteristics and SCI severity. There was no request for completely novel ADs but a need for adaptation of existing ADs to further facilitate transfer and mobility. These findings have implications for the design and development of ADs to better meet the needs of persons with SCI, improve their quality of life, and promote their independence and participation in daily activities.

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Institutional Review Board Statement: Ethical approval for SwiSCI was obtained from the ethics committee of the Canton of Lucerne (EKNZ PB_2016-02608) and subsequently endorsed by the ethics committees of the Cantons Zürich, Basel-Stadt, and Valais, the cantons where the SCI centers are located and from which the population pool was recruited. SwiSCI projects adhere to the applicable guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Owing to our commitment to SwiSCI study participants and their privacy, datasets generated during the current study are not made publicly available but can be provided by the SwiSCI Study Center based on reasonable request (contact@swisci.ch).

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