Research article

Electronic device use by individuals with traumatic spinal cord injury

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Objective: To describe use of several electronic devices among individuals with traumatic spinal cord injury (SCI).

Study Design: Cross-sectional survey.

Setting: Community.

Methods: Potential participants consisted of all individuals with traumatic SCI, ages 7 and older, who had received care through a large academic medical center in the Midwest between January 1, 2003, and January 2, 2013. All eligible individuals received the survey as part of a four-stage mailing that asked questions about electronic device use in addition to questions about demographic and injury-related characteristics.

Results: Mailings were sent to 820 individuals; of those, 451 completed and returned the survey. Descriptive and nonparametric statistics were performed. Individuals with high-level tetraplegia were less likely to use tablet and handheld electronic devices than individuals at all other SCI levels. Individuals aged 65 years and older were less likely to own or use tablet computers and handheld devices than all other age groups.

Conclusion: While electronic devices hold considerable potential as a treatment modality for individuals who have sustained SCI, there is diversity in the particular electronic devices that are used by such individuals due to injury-related characteristics and age.

Introduction

Internet- and mobile-based health interventions, or eHealth/mHealth interventions, are promising modalities for electronically providing health education and tools for patients, healthcare providers, and caregivers.^{1,2} They offer particular opportunities for use with individuals with disabilities and/or chronic illness who are more likely to employ electronic methods to access health information, as compared to individuals in excellent and good health.³ However, electronic devices are not universally accessible for individuals with disabilities. The accessibility of devices to individuals with physical impairments such as traumatic spinal cord injury (SCI) can be problematic because of financial constraints that limit the ability to purchase the devices and/or Internet service, as well as functional impairments that make

controlling the device difficult. Previous research on computer and cell phone use has found lower rates of use among individuals who have sustained SCI as compared to the general population.³⁻⁵ In addition, significant age-related differences in the use of electronic devices have been noted in the general population as well as among people with disabilities.⁶

In order to inform the development and use of eHealth/mHealth interventions for individuals with SCI, it is necessary to first understand patterns of use and ownership as well as the limitations of these modalities. With regard to individuals with SCI, information about the characteristics of those who use various electronic devices, including computers, tablets, and smartphones or other handheld devices, can be beneficial to inform how interventions and assessments are tailored, given both the diversity of physical functioning as well as trends in device use by characteristics such as age.

Although previous research has found electronic methods to be a promising treatment modality for

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communicating health information to individuals with SCI,^{7,8} no study has looked at a population of individuals who have sustained SCI to understand the specific electronic devices they own and use while also considering differences in age groups. Indeed, doing so may inform effective and appropriate electronic interventions to improve health outcomes for individuals with SCI. The purpose of this study is to describe the use and ownership of various mobile and electronic devices by individuals with SCI and to examine patterns of use/ownership by age and functional impairment.

Materials and methods

This study was reviewed by and received the approval of the Institutional Review Board at a Midwestern university. It employed a cross-sectional mail survey design and used the electronic medical records of a large academic medical center to identify potential participants. Those individuals deemed eligible were contacted via a four-stage mail survey between May and July of 2013: a postcard notifying them about the study, a survey packet with introduction letter, a reminder postcard, and (to those who had not yet responded) a second survey packet. For the first group of mailed surveys, a small incentive (US\$3) was included with the survey packet. For those between the ages of 7 and 13, cover letters for both the parents and the child with SCI were included. Responses to the survey could also be entered via a web-based platform if preferred; this option was used by 76 of the 451 respondents.

Subjects

Potential participants included those who had received care through a large academic health system in the Midwestern United States during the 10 years prior to the start of the study (January 2003 to January 2013). Electronic medical records were reviewed by an internal research service to identify a pool of potentially eligible individuals who had a traumatic spinal cord injury and were at least 7 years old. In particular, requests were made for the names of individuals with diagnoses of paralytic syndrome (ICD-9 codes 344.00 to 344.9), fractures of the spine with unspecified SCI (806.00 to 806.6), or SCI without evidence of spinal bone injury (952.00 to 952.9). Names, addresses, ages, sex, and medical diagnoses were provided for 1392 individuals; these were then reviewed for accuracy before a final mailing list with 820 names was generated. At least 36 additional people were removed from receiving the survey instrument because of bad addresses, death, or other causes. A total of 784 were thought to have received the survey packet; of these, 451 individuals returned

completed surveys, for a response rate of 57.5%. Informed consent was obtained from all individual participants in the study.

Variables

Mail surveys were developed by two of the authors (GM and MM) to reflect items asked on the 2010 Pew Internet & American Life Project Tracking Survey,⁹ as well as items that addressed the specific research questions. The survey included questions about ownership and use of computers, tablets, and handheld devices, including smartphones. Questions about the use of each type of device to play electronic games were also included in the survey but are not reported on in this manuscript. After its initial development, feedback about the survey was solicited from an advisory panel of individuals with SCI prior to its finalization and distribution. Participants were asked “Do you own or use...?” each type of device, and were instructed to “check all that apply,” using the following response options: own, use, cannot use due to SCI, do not use, or not applicable.

Demographic information was collected about sex, age, race/ethnicity, and educational status. Injury information also was obtained, including the year the SCI occurred, highest level of SCI, control of hands/arms/trunk, and presence of feeling and motor control below the level of injury.

Statistical methods

Prior to conducting analyses, respondents were organized into five age categories and five injury classifications based on survey responses. The five age categories (7–17, 18–29, 30–49, 50–64, 65 and older) reflected those found in previous reports of device ownership and use.^{9,10} Injury classifications were based on a series of questions—most specifically about level of injury but, failing responses to that question, based on control or sensation below the level of injury as well as in the hands, arms, and trunk. For the purposes of analyses, five categories identified were: high-level tetraplegia (C1–C4), motor complete and motor incomplete; low-level tetraplegia (C5–C8), motor complete and motor incomplete; and paraplegia. It should be noted, however, that the use of the terms “complete” and “incomplete” in this classification strategy are not based on physiological assessments but rather on the descriptions about motor sparing provided by participants. An analytic check of this classification found that individuals with high-level tetraplegia, motor complete, and low-level tetraplegia, motor complete, were less likely to have control over their hands, arms, and

trunk, while individuals with paraplegia were more likely to have control over their hands, arms, and trunk ($P < 0.001$ for all analyses).

Descriptive analyses (including means, standard deviations, and frequencies) were then performed to understand the use of electronic devices according to injury level and age group. In the survey, participants were asked to “check all that apply” with regard to ownership or use of devices; these response choices were then combined to calculate the percentages presented. Listwise deletion was used and cases where there was missing data were not included in the analysis. χ^2 analyses were conducted to determine significant differences in devices owned/used between groups with different ages and injury classifications. Bonferroni corrections were applied where appropriate to control for type I error.

Results

Table 1 shows the demographic data on participants. A total of 451 individuals completed and returned the survey. Participants ranged in age from 7 to 96 years old; the mean age was 47.73 years ($SD = 16.92$). Most participants were male (71.2%), in the 50–64 age range (36.5%), and self-identified as White (85.4%). There was diversity in injury-related characteristics, with the most common duration of a SCI being five years or less (28.6%) and the most frequent injury type being paraplegia (47.5%). Of note, most participants were not currently in school (88.5%), and of those who indicated completion of less than a high school education, 50% were currently enrolled in school at grade 12 and below.

The percentage of participants who indicated owning and/or using each of the three types of electronic devices (computer, tablet computer, handheld device) is displayed in Table 2 according to age group. Within the computer category, a majority of participants across all age groups indicated owning/using a desktop and/or laptop. Within the tablet computer category, with the exception of participants aged 65 and older, respondents were more likely to indicate owning/using an iPad than any other tablet computer device. Across all age groups most participants were not likely to own/use more than one device per category ($P < 0.001$ for all analyses).

Table 3 displays the percentage of participants who owned and/or used computers, tablets, and handheld devices according to different injury classifications of SCI. Individuals with high-level tetraplegia, motor complete, were significantly less likely to own/use iPads than all other groups ($P < 0.001 - < 0.05$ for all analyses).

Table 1 Demographics of participants ($N = 451$)

Demographic characteristics	% of participants
Sex	
Male	71.2
Female	27.9
No response	0.9
Age	
7–17	3.8
18–29	13.7
30–49	31.6
50–64	36.5
65+	14.2
Race/ethnicity	
White	85.4
Black/African American	9.5
Hispanic/Latino	1.3
Asian	0.7
Native Hawaiian/Pacific Islander	0.2
American Indian/Alaska Native	1.3
Other	2.4
Education	
Less than high school	3.6
High school grad	21.6
Some college/college grad	37.3
No response	37.5
Years with SCI	
0–5	28.6
5–10	17.8
11–20	21.0
21–30	13.9
31–40	9.3
41+	4.1
No response	5.3
Injury classification	
C1–C4, motor complete	9.3
C1–C4, motor incomplete	10.8
C5–C8, motor complete	16.6
C5–C8, motor incomplete	14.2
Paraplegia	48.7

These individuals were also significantly less likely to own/use handheld iPhone devices than individuals with low-level tetraplegia, incomplete, and with paraplegia ($P < 0.001 - < 0.05$ for all analyses).

Fig. 1 shows the percentage of participants who reported being unable to use each type of device because of their spinal cord injury. Individuals with high-level tetraplegia, motor complete, were significantly more likely to report that they were unable to use tablets than individuals with low-level tetraplegia, motor incomplete, and paraplegia ($P < 0.001$ for all analyses). Individuals with high-level tetraplegia, motor complete, were also more likely to report being unable to use handheld devices because of their SCI than individuals in all other injury classifications ($P < 0.001 - < 0.05$ for all analyses).

Fig. 2 compares the use of computers, tablets, and handheld electronic devices among the subset of study participants age 18 and older ($n = 434$) to national surveys of American adults in the general population

Table 2 Percentages of participants who owned/used each type of electronic device according to age group (N = 451)

Device	7–17 (n = 17)	18–29 (n = 62)	30–49 (n = 143)	50–64 (n = 165)	65+ (n = 64)	χ^2 *
Computer	88.2	80.6	93.0	87.9	89.1	Ns
Desktop	58.8	54.8	71.3	58.8	54.7	Ns
Laptop	70.6	62.9	69.9	66.7	64.1	Ns
Both	41.2	37.1	48.2	37.6	29.7	Ns
Tablet computer	88.2**	71.0**	52.4	36.4**	29.7**	42.768
iPad	58.8	54.8**	33.6	22.4	20.3	31.835
Android	23.5	17.7**	15.4	6.7**	3.1**	40.600
Kindle Fire	23.5	8.1	14.0	7.3	9.4	Ns
e-Book reader	5.9	12.9	10.5	6.1	7.8	Ns
Other	5.9	6.4	2.8	1.8	1.6	Ns
2+ devices	35.3**	21.0	16.1	5.4**	11.0	23.18
Handheld device	82.4**	79.0**	58.7**	33.3**	17.2**	77.139
iPod touch	35.3**	27.4**	16.8	3.0**	3.1	43.22
iPhone	41.2	45.2**	30.8	18.2**	14.1	25.429
Android	41.2	41.9**	29.4	14.5**	3.1**	40.600
Apple and Android	23.5	17.7**	10.5	0.6**	1.6	33.638

* df = 4; P < 0.001

** More likely to use device than at least one other age group at the 0.05 significance level with Bonferroni adjustment.

Ns = Non-significant

in the United States.^{11–13} The use of all types of devices is lower among our sample of adults with SCI as compared to the national sample of American adults.

Discussion

While health information and resources (e.g. patient portals, recruitment marketing, medical electronic newsletters, etc.) are increasingly being communicated electronically,¹⁴ our findings suggest SCI does impact ability to access electronic devices. Specifically, our study found that individuals with different functional abilities had

different patterns of device use and ownership. As noted in the results, individuals with high-level tetraplegia are less likely to own and/or use certain tablet and handheld devices than those with lower levels of injury but are more likely to use desktop or laptop computers (particularly those with motor-complete high tetraplegia). This pattern may reflect the number of accessories and input/interaction methods to facilitate accessibility that are available on computer systems, including screen readers, voice-recognition software, and other peripheral devices. More important, though, device use may depend heavily

Table 3 Percentages of participants who owned/used each type of electronic device by injury classification (N = 451)

Device	C1–C4 Motor complete (n = 42)	C1–C4 Motor incomplete (n = 49)	C5–C8 Motor complete (n = 75)	C5–C8 Motor incomplete (n = 65)	Paraplegia (n = 220)
Computer	92.9	93.9	85.3	89.2	87.7
Desktop	71.4	63.3	62.7	58.5	60.0
Laptop	64.3	77.6	73.3	64.6	63.2
Both	42.9	56.9	50.7	33.8	35.5
Tablet computer	33.3	51.0	53.3	49.2	46.8
iPad	19.0	38.8	41.3	27.7	30.5
Android	7.1	8.2	9.3	13.8	12.3
Kindle Fire	9.5	14.3	8.0	10.8	10.9
e-Book reader	2.4	4.1	10.7	7.7	10.5
Other	4.8	6.1	1.3	1.5	2.7
2+ devices	4.8	16.3	14.7	6.2	7.7
Handheld device	33.3	36.7	50.7	47.7	51.4
iPod touch	7.1	8.2	14.7	10.8	13.6
iPhone	14.3	26.5	36.0	23.1	26.4
Android	14.3	8.2	14.7	29.2	27.7
Apple and Android	2.4	2.0	4.0	4.6	10.9*

*More likely to use device than at least one other age group at the 0.05 significance level with Bonferroni adjustment. χ^2 (df = 4) = 9.950; P = 0.041.

Figure 1. Inability to use electronic device due to SCI in study participants according to injury level (N = 451).

Computer includes desktop and/or laptop computer. Tablet computer includes iPad, Android, Kindle Fire, e-Book reader, and/or other tablet computer device. Handheld device includes iPod touch, iPhone, and/or Android handheld device.

on reason for use—a facet that was not reflected in the survey—with certain modalities being specifically designed for different types of use (e.g., simple data entry and accessing electronic health records or more media-rich interactive experiences).

Of course, ownership and access of computers and electronic devices may be in part due to other factors such as cost of the device and associated Internet service.^{6,11} The purchase of a mobile device capable of what individuals may need for their health is an added cost and a personal purchase since people rarely share mobile devices. However, computers are frequently already present in most homes and are shared, thus mitigating the cost and making the technology more accessible.

As might be expected, participants with motor-complete high-level tetraplegia were less likely to report being able to use tablet and handheld devices due to their SCI, as compared to individuals with other levels of injury. Significantly fewer individuals with lower-level injuries reported a similar inability to use devices due to their injury. This is consistent with aforementioned findings that individuals with higher levels of injury are most likely to use computer devices. One finding in this area which remains unexplained is the report by several individuals with paraplegia that they were unable to use computers (and to a much lesser extent tablets and handheld devices) because of their SCI; given that paraplegia alone should not reduce the hand and arm functioning needed to access either computers or the electronic devices in the same way that those without SCI access them, these types of responses may require additional exploration and highlight the limitations of the survey.

Another observation worth noting is the variation in the use of electronic devices according to age group. While ownership/use of desktop computers is

Figure 2. Percentage of electronic device use in American adults from Pew reports versus study participants 18+ years of age. Note: For American adults, the data consist of averages of electronic device use in 2013, as reported by the Pew Research Center.^{11–13} For adults with SCI in the study population, n = 434.

comparable across all age groups in our study, there are important age differences relative to more recent innovations, such as tablet computers and handheld devices. Those devices are owned or used significantly more by the younger age groups in our study (7–17, 18–29, and 30–49), a pattern that resembles that of national samples,^{12,15} although we consistently found lower ownership/use rates across all age groups with SCI. These findings point to the value of considering age diversity in addition to injury-related characteristics among individuals with SCI.

Taken together these findings highlight the importance of tailoring how information is provided to the audience one hopes to attract. If providing information or interventions for adults with SCI age 50 or older, it appears critical to format it to be viewed and/or accessed on computers or laptops. In contrast, information aimed at adolescents and young adults is likely to benefit from formatting that fits and can be viewed on mobile devices. Similarly, the injury classification of the audience may suggest the type of device that programs, information, and/or interventions need to be formatted for in order to enhance access by that group. Specifically, using a tablet or smartphone app to deliver information or interventions may be limiting, and creating browser-based versions may be important to maximize reach to people with all levels of SCI.

Given trends in device use in the general population over the past 5 years, it may be expected that there has been a similarly sharp rise in the use of electronic devices among individuals with SCI, with likely similarities in relative use based on severity of injury as well as age differences. However, these data suggest that handheld devices may not be an appropriate method to electronically communicate health information to individuals with SCI, given the considerably lower percentage of use among our sample as compared to national statistics. Given clear differences between the two groups it would be important for future studies to further compare use of electronic devices among individuals with SCI and national samples.

Accordingly, for medical professionals using electronic methods to communicate health information to patients, it is thus necessary to consider the perceived inability to operate tablet computers and handheld devices among patients with higher levels of injury. With consideration of differences in ability to use electronic devices due to SCI level, medical professionals can improve electronic communication of health resources among individuals with SCI.

The area of electronic device use and ownership by individuals with SCI and other disabilities is one that

deserves additional attention by researchers, healthcare providers, and developers of mobile technology. Information collected from quantitative surveys would be enhanced by including additional demographic characteristics such as income and access to Internet services and impairment characteristics beyond those imposed by SCI (e.g. cognitive limitations, sensory impairments). In addition, allowing respondents to provide details about how frequently and why they use their devices (e.g. work, information collection, social networking), the reasons that they do not or no longer use all or some electronic devices, and the perceived impact of impairment on use of each type of device would provide significant data for the development of both education and technology. Clinical research examining differences in perceived versus actual ability to use various electronic devices could also inform the need for education regarding accessibility features. Finally, developers are encouraged to continue to explore features of hardware as well as mobile apps, websites, and other software components which may impact use by individuals with limited functioning in their hands and arms.

Limitations

As with any study, there are limitations to the current research findings. Among these is the lack of diversity in our sample, the majority of whom were non-Hispanic White, and all of whom were recruited from the same academic medical center. Given the known disparities that exist based on race and ethnicity,¹⁶ future studies may seek to look at electronic device use among individuals with SCI from other racial groups.

Similarly, most participants indicated paraplegia as the highest level of injury. Future studies may seek to look at the present variables not only with larger samples of individuals with SCI, but also with more diversity in injury-related characteristics.

This study is also limited in that we did not inquire about factors which are known to impact device ownership and use. Two items that may have been particularly useful to include are a measure of income and further queries about the reasons behind device use or non-use. Income, health insurance, and access to assistive technology loan programs may impact not only the ability to pay for the devices, but also the costs associated with the high-speed Internet that is needed for health information, such as access to a personal electronic medical record.

Finally, this study is limited by the point in time in which it occurred. Electronic device use and ownership changes very rapidly, as do the features of those devices, including those designed to increase accessibility. As such, results from this study can only be taken

to reflect ownership and use of the specific types of electronic devices that were common at the point in time that this study occurred.

Conclusion

This study provides important information about the use and ownership of electronic devices by individuals with SCI that can inform the design and use of eHealth/mHealth studies, programs, and dissemination strategies. When this study was conducted, individuals with SCI were most likely to own or use a computer as opposed to a tablet or handheld mobile device. Device use was influenced by both age and severity of injury. Since that time it seems likely that the percentages of individuals using specific types of devices have changed, given increasing availability and accessibility of tablets and mobile devices.

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