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Assessing Patient Proficiency with Internet-Connected Technology and Their Preferences for E-Health in Cirrhosis

Kathleen P. Ismond[1] · Tannaz Eslamparast[1] · Kamal Farhat[1] · Michael Stickland[2] · John C. Spence[3] ·
Robert J. Bailey[4] · Juan G. Abraldes[1] · Jude A. Spiers[5] · Puneeta Tandon[1]

Abstract

There is a rapidly evolving need for e-health to support chronic disease self-management and connect patients with their healthcare teams. Patients with cirrhosis have a high symptom burden, significant comorbidities, and a range of psychological and cognitive issues. Patients with cirrhosis were assessed for their readiness and interest in e-health. Adults attending one of two outpatient cirrhosis clinics in Alberta were recruited. Eligible participants were not required to own or have experience with digital technologies or the Internet. Medical history, socioeconomic status, and attitudes regarding e-health, the Computer Proficiency Questionnaire, and the Mobile Device Proficiency Questionnaire were used to describe participants' knowledge and skills. Of the 117 recruited patients, 68.4% owned a computer and 84.6% owned a mobile device. Patients had mean proficiency scores of 72.8% (SD 25.9%) and 69.3% (SD 26.4%) for these devices, respectively. In multiple regression analyses, significant predictors of device proficiency were age, education, and household income. Most patients (78.7%) were confident they could participate in videoconferencing after training and most (61.5%) were interested in an online personalized health management program. This diverse group of patients with cirrhosis had technology ownership, proficiency, and online behaviours similar to the general population. Moreover, the patients were very receptive to e-health if training was provided. This promising data is timely given the unique demands of COVID-19 and its influence on self-management and healthcare delivery to a vulnerable population.

Abbreviations

HE	hepatic encephalopathy
MELD-NA	model for end stage liver disease – sodium
CPQ	Computer Proficiency Questionnaire
MDPQ	Mobile Device Proficiency Questionnaire
CP	Child-Pugh score

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✉ Puneeta Tandon
  ptandon@ualberta.ca

1 Division of Gastroenterology, Liver Unit, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta T6G 2X8, Canada

2 Department of Medicine, Faculty of Medicine and Dentistry, University of Alberta, Edmonton, Alberta T6G 2X8, Canada

3 Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, Alberta T6G 2X8, Canada

4 Division of Gastroenterology, Royal Alexandra Hospital, of Alberta, Edmonton, Alberta T6G 2X8, Canada

5 Faculty of Nursing, University of Alberta, Edmonton, Alberta T6G 2X8, Canada

Introduction

All chronic liver diseases eventually progress to cirrhosis, a common endpoint where the accumulation of scar tissue causes portal hypertension-related complications and impedes normal liver function. Patients with compensated cirrhosis have a median survival time greater than 12 years [1]. Once the liver progresses to the decompensated state, indicated by complications such as ascites, hepatic encephalopathy (HE), or variceal bleeding, the median survival decreases to approximately two years [1]. Across the

cirrhosis trajectory, patients receive complex medical care involving preventative screening (e.g., cancer, varices), treating complications, and managing their high symptom burden, including but not limited to pain, fatigue, and depression [2–4].

E-health solutions (e.g., websites, telemonitoring, mobile apps designed to perform specific functions) to support patient self-management and health services have been introduced in many chronic disease populations, such as cardiovascular diseases, fibromyalgia, Parkinson's disease, chronic kidney disease, HIV, cancer, and mental illness [5–9]. In cirrhosis, the "Patient Buddy" app has been created for individuals with a history of hepatic encephalopathy [10]. The term "e-health" is used as both a noun and verb indicating the intersection of health, information, communication technology, and various stakeholders [11]. E-health has been associated with improvements in general self-management skills, communications with healthcare professionals, quality of life, physical function, pain management, and health outcomes [5].

An underlying assumption of e-health is that users have ready access to Internet-connected digital technology and the skills to use it effectively. The reality is that the "digital divide" persists along lines of social inequalities (i.e., education, urban versus rural, income, age, and immigration status [12–14]) and influences the access and the ability to use e-health. Two barriers are common in cirrhosis, prevalence of low socioeconomic status [15–17] and that nearly one third of patients are 65 years or older [18]. From a patient's perspective, additional barriers may include cirrhosis severity, physical disabilities, or cognitive abilities [19, 20].

The purpose of this study was to characterize the readiness of patients with cirrhosis for e-health by: (1) assessing their Internet access frequency and digital technology ownership; (2) determining their digital literacy proficiency and identifying relevant predictors; and, (3) ascertaining their general attitudes and receptiveness to video conferencing and online health management programs by age group. Aims 1 and 2 considered the severity of cirrhosis as indicated by the Child-Pugh score [21, 22]. By understanding the skills and preferences of patients with cirrhosis, e-health solutions can be better designed to meet their unique needs and abilities. In turn, these e-health products may achieve a wider adoption and longer period of use leading to improved patient health outcomes [23].

Methods

A survey-based, cross-sectional study was used to capture self-reported information regarding computer and Internet proficiency and attitudes in patients living with cirrhosis. The study was approved by the Health Research Ethics Board at the University of Alberta (Pro00082756). A convenience sample of consecutively consenting patients was recruited from outpatient liver clinics at two tertiary care hospitals located in western Canada from July 2018 to February 2019.

Participants

Eligibility criteria required that participants be: 18 years of age or older; have a confirmed diagnosis of cirrhosis as determined by imaging, medical history, transient elastography, or liver biopsy; could provide informed written consent; and, could read and write in English. Ineligible participants were transplant recipients or individuals who were unable to provide consent. There was no requirement for having previous digital technology or Internet access. This study had an intended enrollment target of 125 participants based upon previous studies of this kind [24–26].

Procedure

After written informed consent was obtained, patients were asked to complete a survey in a paper and pencil format to minimize bias regarding technology proficiency. It was completed in a clinic exam room. The research assistant remained nearby to answer questions and review the responses for completeness. If a patient asked the research assistant for a digital version of the survey, a link to an the online version was provided via REDCap [27].

Participant Characteristics

To characterize the cohort, each participant's personal health number was used to access their electronic health records: age (years), biological sex, liver disease etiology, prognostic measures (model for end-stage liver disease-sodium [MELD-Na] [28] and the Child-Pugh score, both determined with the patient's most recent blood tests), history of HE, cancer history, significant comorbidities, disabilities, and current medications. Patients completed a general survey about their level of education, household income, digital technology devices they owned, frequency of Internet use, and online communication preferences.

Outcome Measures

The Computer Proficiency Questionnaire (CPQ) captures information about the patient's computer and Internet skills [23]. The CPQ contains six domains assessing skills regarding computer basics, printing, communication, Internet, calendar, and entertainment. The Mobile Device Proficiency Questionnaire (MDPQ) characterizes the patient's skills with smart devices across eight domains: mobile device basics, communication,

data and file storage, Internet, calendar, entertainment, privacy, and troubleshooting and software management [20]. The CPQ and MDPQ used a 5-point Likert scale (1=never tried; 2=not at all; 3=not very easily; 4=somewhat easily; and 5=very easily) and the questionnaires were scored as previously described [20, 23]. The total possible points for the CPQ and MDPQ were 30 and 40, respectively. These validated questionnaires have demonstrated significant relationships with the length and frequency of use of a specific technology [20]. Internal consistency for each scale is high with Cronbach's $\alpha \geq$.98 [20, 23, 29].

A third questionnaire captured patient receptiveness about video calling with healthcare professionals (see Supplemental-Fig. 1). It was developed in-house for this study and was not validated before use. Patient responses to each of the seven statements were answered with a Likert scale: 1=totally disagree, 2=somewhat disagree, 3=neutral, 4=somewhat agree, and 5=totally agree. Online delivery of healthcare programming was explored with the question "If our team provided you with the training to make you more comfortable with using the Internet, how interested would you be in participating in a personalized health management program delivered by an Internet-based app (e.g., receiving exercise information, dietary information, reminders, and motivational tips)?" Patient preferences regarding four discrete functional elements for the hypothetical personalized online program were captured with a 5-point Likert scale: 1=not helpful at all, 2=somewhat unhelpful, 3=neutral, 4=somewhat helpful, and 5=extremely helpful (see Supplemental-Fig. 2).

Data Analysis

Descriptive statistics (mean, standard deviation, median, frequency) were generated for participants organized by Child-Pugh (CP) classification (A *vs.* B/C). Between group comparisons were completed for categorical variables using the χ^2 test or Fisher exact test, for continuous variables using independent samples *t* test, and ordinal variables using the Mann Whitney U test. Correlation analyses between CPQ and MDPQ scores and the continuous variables of age, CP score, and MELD-Na score were completed. To construct the regression models, significant variables (p<0.05) from the correlational analysis were included with dichotomous (sex, HE, comorbidities, visual impairment) and categorical (cirrhosis etiology, household income, education) variables and then regressed against either CPQ or MDPQ. Non-significant predictors were eliminated manually one by one and the regression was rerun. Only variables that significantly contributed to the models were retained. When assessing attitudes and preferences regarding video calling and online programming, the Kruskal-Wallis H test was used to determine if age differences existed. Specifically, with alpha set at *p*<.05, pairwise comparisons between the age groups were performed using Dunn's (1964) procedure with a Bonferroni correction for multiple comparisons. Missing survey data were obtained

from the study participant. All analyses were performed using IBM SPSS Statistics for Windows, Version 24.0 (IBM Corporation, Armonk, NY).

Results

Description of Participants

One hundred seventeen patients were recruited (age range: 24 to 83 years; MELD-Na score range: 6 to 33; Table 1) of which 72 (61.5%) were men. Significant differences were found between the two study groups (Child-Pugh A versus B/C) for mean MELD-Na score, ascites, diuretics, and lactulose and/or rifaximin (*p* >.001 for each) which were consistent with cirrhosis severity. Many patients had significant comorbidities: diabetes (*n*=36; 30.8%); arthritis (*n*=33; 28.2%); any cancer (*n*=33; 28.2%); asthma, (*n*=14; 12.0%); or, myocardial infarction (*n*=10; 8.5%). A total of 14 (12.0%) participants reported a visual impairment. More than half of the respondents had attended post-secondary education (e.g., college, professional courses).

Digital Technology Ownership and Internet Behaviours

Participants' responses to questions regarding their digital technology ownership, Internet access, attitudes are presented in Table 2. Disease severity indicated by Child-Pugh scores (A vs B/C) was not associated with any of the relevant variables. From a list of 10 common digital technology devices, 90 (76.9%) patients owned a smartphone. This was followed by ownership of laptops (53.8%), desktop computers (48.7%), tablets (43.6%), and smart televisions (31.6%) which are Internet connected and function like a television and computer. Only one patient stated that they did not own any of the devices. Nine (7.7%) patients did not own a smart device nor a computing system while 71 (60.7%) owned both. Daily Internet use was reported by 72 (61.5%) patients. Only 14 (12.0%) patients had never accessed the Internet. The Internet was accessed either frequently or very frequently for communication purposes by 69 (59.0%) patients. One hundred (85.5%) patients reported that digital technology was most helpful for communicating with others. Though only 52 (44.0%) patients used the Internet frequently or very frequently to obtain information, 78.6% stated that digital technology helped them to make more informed decisions. In all, 82.9% stated that life was better because of digital technology use.

Digital Technology Proficiency

Since the CPQ and MDPQ assess technology proficiency in four of the same areas (communication, Internet,

Table 1 Characteristics of participants by liver disease prognosis

Characteristic	Cohort	Child-Pugh A	Child-Pugh B or C	*p*-value
Participants (n)	117	60	57	
Men	72 (61.5%)	38 (63.3%)	34 (59.6%)	.682
Mean age in yrs (SD)	58.2 (11.2)	59.1 (9.3)	57.2 (13.0)	.368
Etiology of cirrhosis:				.002
● Alcohol	39 (33.3%)	13 (21.7%)	26 (45.6%)	
● Hepatitis C	31 (26.5%	22 (36.7%)	9 (15.8%)	
● NAFLD[a]	25 (21.4%)	17 (28.3%)	8 (14.0%)	
● Other[b]	22 (18.8%)	8 (13.4%)	14 (24.6%)	
MELD-Na mean (SD)	12.5 (11.0)	8.8 (2.2)	16.9 (6.3)	< .001
Listed for liver transplant	18 (15.4%)	6 (10.0%)	12 (8.8%)	.098
Dyslipidemia	32 (27.4%)	16 (26.7%)	16 (28.1%)	.865
Hypertension	48 (41.0%)	24 (40.0%)	24 (42.1%)	.817
Ascites	33 (28.2%)	3 (5.0%)	30 (52.6%)	< .001
History of variceal bleeding	21 (17.9%)	5 (8.3%)	16 (28.1%)	.005
Comorbidities[c]	77 (65.8%)	39 (65.0%)	38 (66.7%)	.849
On diuretics	61 (52.1%)	16 (26.7%)	45 (78.9%)	< .001
On lactulose and/or rifaximin	37 (31.6%)	0 (0%)	37 (31.6%)	< .001
Education:				.778
● Grade 8	12 (10.3%)	7 (11.7%)	5 (8.8%)	
● High school diploma	34 (29.1%)	16 (26.7%)	18 (31.6%)	
● Post-secondary school	71 (60.7%)	37 (61.7%)	34 (59.6%)	
Household income:				.590
● Participant chose not to report	10 (8.5%)	6 (10.0%)	4 (7.0%)	
● <$25,000	35 (29.9%)	15 (25.0%)	20 (35.1%)	
● $25,000 to $50,000	20 (17.1%)	12 (20.0%)	8 (14.0%)	
● >$50,000	33 (28.2%)	27 (45.0%)	25 (43.9%)	

[a]Includes non-alcoholic fatty liver disease (NAFLD) and cryptogenic cirrhosis

[b]Includes hepatitis B, primary biliary cholangitis (PBC), primary sclerosing cholangitis (PSC), and autoimmune hepatitis

[c]If the individual had one or more of the following: myocardial infarction, diabetes, asthma, arthritis, or any cancer

calendar, and entertainment), and a strong positive correlation ($r=0.93$) was observed between the two sets of scores.

Common markers for disease severity (e.g., the MELD-Na score, Child-Pugh score) were not related to either the CPQ or MDPQ. The only significant correlate was age which was included in the subsequent multiple regression analyses. The final CPQ model explained 40% of the variance (adjusted $R^2 = 0.403$), $F(6, 110)=14.071$, p<0.001 (Table 3). Educational background impacted CPQ scores where graduates from grade 8 or high school had lower scores (26.4% and 23.3%, respectively) than their post-secondary peers. Age had a significant influence in the multiple regression model where each year of life changed the CPQ score by -0.8% (reducing proficiency). For the household income variable, only the sub-category of less than $25,000 significantly influenced the CPQ by -10.8% (p=.02). These variables were also significant correlates

for the MDPQ model with no difference in direction of influence of the predictors and no additional predictors identified (Table 3). When examining the effect size of the predictors for the CPQ and MDPQ, the patient age variable (partial $\eta^2=.17$ and partial $\eta^2=.25$, respectively) outperformed education considering its cumulative yearly impact and the mean age of the study population of 58.2 years.

Video Calling Preferences

Figure 1 presents the responses to questions regarding patient opinions about this online form of communication. Most patients were receptive to using video calling with health care professionals and only 16 (13.7%) were totally against it. Seventy-nine (67.5%) patients expected that video calling with a healthcare professional would be confidential. Patients expected that video calling would

Table 2 Characterizing patient technology ownership, Internet access, and perceptions by liver disease prognosis

Characteristic	All	Child-Pugh A	Child-Pugh B or C	*p*-value
Participants (n)	117	60	57	
Owns a smart device	99 (84.6%)	52 (86.7%)	47 (82.5%)	.528
Owns a computer/laptop	80 (68.4%)	40 (66.7%)	40 (70.2%)	.683
Does not own technology	1 (0.9%)	1 (1.7%)	0 (0%)	1.0
Frequency of Internet use:				.552
• Daily	72 (61.5%)	34 (56.7%)	38 (66.7%)	
• Weekly	15 (12.8%)	10 (16.7%)	5 (8.8%)	
• Monthly	16 (13.7%)	8 (13.3%)	8 (14.0%)	
• Not accessed	14 (12.0%)	8 (13.3%)	6 (10.5%)	
Patients frequently or very frequently used the Internet for[a]:				
• Communicating (e.g., email, Skype)	69 (59.0%)	33 (55.0%)	36 (63.2%)	.370
• Accessing information (e.g., news, health, government)	52 (44.0%)	25 (41.7%)	27 (47.4%)	.535
• Performing tasks (e.g., banking, online shopping)	49 (41.9%)	25 (41.7%)	24 (42.1%)	.962
• Leisure activities/entertainment (e.g., games, music, film, photos)	56 (47.9%)	26 (43.3%)	30 (52.6%)	.314
Digital technology helps with:				
• Communication (Y/N)	100 (85.5%)	53 (88.3%)	47 (82.5%)	.367
• Saving time (Y/N)	80 (68.4%)	43 (71.7%)	37 (64.9%)	.432
• Making more informed decisions (Y/N)	92 (78.6%)	48 (80.0%)	44 (77.2%)	.711
• Being more creativity (Y/N)	75 (64.1%)	39 (65.0%)	36 (63.2%)	.836
Life is better because of technology use (Y/N)	97 (82.9%)	50 (83.3%)	47 (82.5%)	.900
CPQ score, mean (SD)	72.8% (25.9%)	71.6% (26.2%)	74.1% (25.9%)	.610
MDPQ score, mean (SD)	69.3% (26.4%)	69.3% (26.2%)	69.3% (27.0%)	.998

CPQ Computer Proficiency Questionnaire, *MDPQ* Mobile Device Proficiency Questionnaire, *N* no, *SD* standard deviation, *Y* yes

[a]Survey question used a 5-point Likert scale where 1=very rarely and 5=very frequently; data presented are the sums for responses "frequently" and "very frequently"

be both quick to learn and easy to do thereafter. Seventy-seven (65.8%) patients agreed that video calls with healthcare professionals would be associated with a safe feeling. When asked if they could make video calls on

Table 3 Standard multiple regression analyses against proficiency scores

Variables		*B*	*SE_B*	t	p-value	Partial Eta (η^2)
(A) Computer Proficiency Questionnaire (CPQ)						
Constant		134.911	10.480	12.873	<.001	.601
Household Income	• Not reported	-3.915	7.046	-.556	.580	.003
	• <$25,000	-10.816	4.656	-2.323	.022	.047
	• $25,000 to $50,000	-4.434	5.446	-.814	.417	.006
	• >$50,000	0[a]				
Education	• Up to Grade 8	-26.386	6.630	-3.980	<.001	.126
	• Up to Highschool	-23.261	4.397	-5.290	<.001	.203
	• Up to Post-secondary	0[a]				
Age		-.830	.174	-4.770	<.001	.171
(B) Mobile Device Proficiency Questionnaire (MDPQ)						
Constant		143.287	10.290	13.925	<.001	.638
Household Income	• Not reported	-4.392	6.918	-.635	.527	.004
	• <$25,000	-13.375	4.572	-2.925	.004	.072
	• $25,000 to $50,000	-4.803	5.347	-.898	.371	.007
	• >$50,000	0[a]				
Education	• Up to Grade 8	-25.263	6.510	-3.881	<.001	.120
	• Up to Highschool	-21.322	4.317	-4.939	<.001	.182
	• Up to Post secondary	0[a]				
Age		-1.031	.171	-6.032	<.001	.249

B regression coefficient, *SE_B* standard error

[a]Reference variable

their own, only 25 (29.1%) patients totally agreed. When asked if they were provided with training, 56 (47.9%) patients totally agreed that they could use video calling.

To determine the impact of patient age on their video calling preferences, a Kruskal-Wallis H test was run with patients categorized into three groups: Group A, 24-55 years ($n=40$); Group B, 56-63 years ($n=39$); and, Group C, 64-83 years ($n=38$). Patient age had a significant impact on responses for questions 1, 3, 4, and 6 (see Fig. 1 for survey results). Younger patients (Group A) were more receptive and positive about the use of video calling with healthcare professionals than older patients in Groups B or C (see Supplemental-Table 1 for pairwise comparison details).

Online Personalized Exercise Program Preferences

Regarding interest in an online personalized health management program, 72 (61.5%) patients were somewhat or very interested, 12 (10.2%) were neutral, 21 (17.9%) were somewhat or very disinterested, and 12 (10.2%) did not know. Patient responses to the four elements of the online program (e.g., video content and motivational messaging) ranged across the entire Likert scale; a considerable proportion (range: 21.3% to 36.7%) of respondents did not consider these as helpful (see Fig. 2 for survey results). A single element was neither favoured nor disliked by the entire study group. The Kruskal-Wallis H test identified that preferences about text messaging motivational tips were significantly impacted by patient age with younger

patients preferring it more than older ones (Group A vs Group C; see Supplemental-Table 2 for pairwise comparison details).

Discussion

To our knowledge, this is the first study evaluating digital literacy skills, Internet access, and digital technology preferences of patients with cirrhosis. Within our cohort, the main findings of this study were: (1) most patients owned or used technology in their homes with the majority accessing the Internet daily; (2) skills using either computers or mobile devices was moderate and significant predictors of proficiency were age, education, and household income less than $25,000 per year; and, (3) most were receptive to video calling with healthcare professionals and interested in online personalized health management programming.

Technology ownership in this cirrhosis study was similar to data presented in the Internet and digital technology component of the 2016 General Social Survey for Canada [30]: (smart device: 76% vs. 85%; computer: 71% vs. 68.4%, respectively). Our study participants reported that technology was even more useful for communication than the national average (86% vs. 77%, respectively), including its use to make informed decisions (79% vs. 52%, respectively) be more creative (64% vs. 36%, respectively). Overall, 83% of study patients believed that life was better because of technology versus 60% for Canadians of a similar age range. The median household income for the study
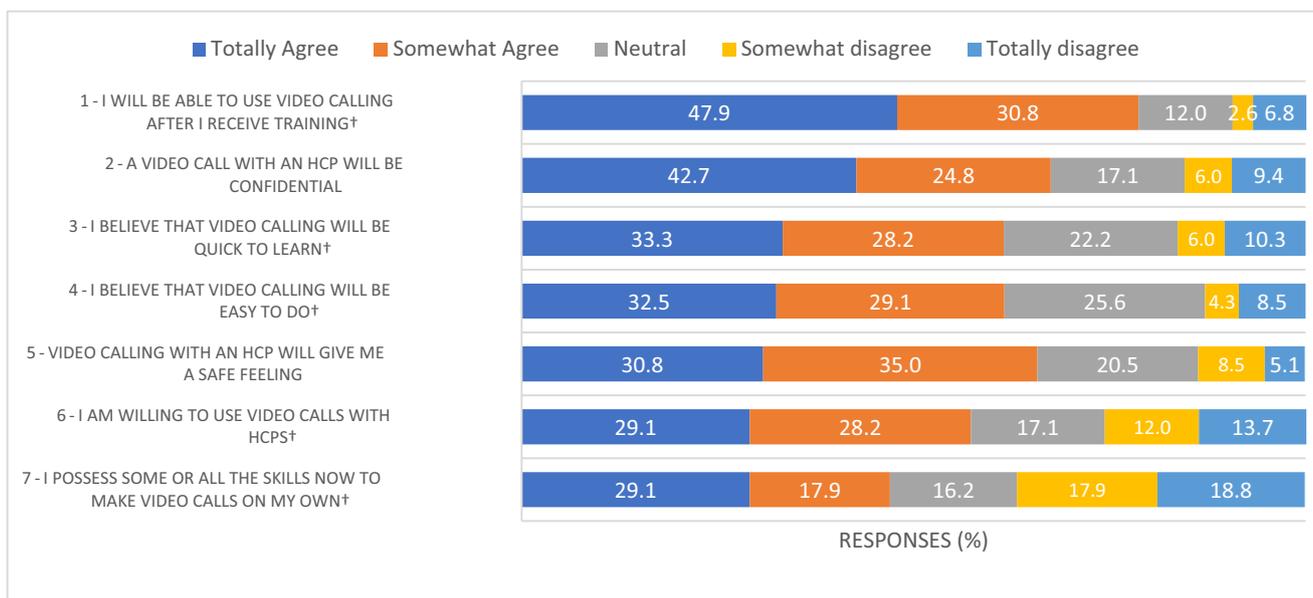

Fig. 1 Opinions of study patients ($n=117$) regarding video calling. † $p<.05$ for the Kruskal-Wallis H test indicating if there were differences by patient age group: 24-55 yrs ($n=40$), 56-63 yrs ($n=39$), and 64-83 yrs ($n=38$)

Fig. 2 Preferences of study patients (n=117) regarding online delivery of personalized exercise programming. † p<.05 for the Kruskal-Wallis H test indicating if there were differences by patient age group: 24-55 yrs (n=40), 56-63 yrs (n=39), and 64-83 yrs (n=38)
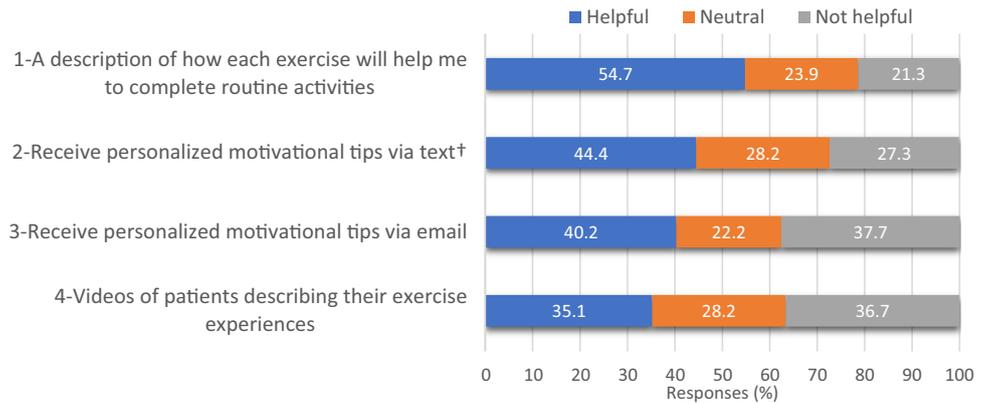
group of $25,000 to $50,000 was below the average for the Edmonton region ($87,225) and province ($93,835) [31]. Despite limited finances, study patients had similar rates of technology ownership, Internet habits, and attitudes as other Canadians. This suggests that study participants value Internet and communications technology and financially prioritize these. Interestingly, when participants were grouped by their Child-Pugh score, no significant differences were found suggesting that these behaviours may be independent of cirrhosis severity.

The scores on the computer and mobile device proficiency questionnaires (CPQ and MDPQ, respectively) indicate that patients had moderate proficiency with these technologies. For comparison, one study reported a mean CPQ score of 33.3% (n=276) was attained by people with minimal computer experience while a mean score of 81.2% (n=76) was associated with several years of computer experience and computer ownership in older adults [23]. A second study reported a mean CPQ score of 78.2% for 116 adults from the general population [29]. MDPQ scores have been significantly correlated with both the length and frequency of use of mobile devices in adults (n=95) [20]. Specifically, MDPQ scores for the general population have ranged between 48% to 92% in the United States [20] and 33% to 90% in Spain [29]. Overall, our study patients had computer and mobile device proficiencies comparable to their healthy counterparts.

Measures of cirrhosis severity (MELD-Na, CP score), comorbidities, history of HE, and visual impairments were not significant predictors of either CPQ or MDPQ scores. However, the well-described barriers of age, education, and income impacted digital technology proficiency [24, 26, 32, 33], were significant predictors for our cirrhosis study group. Within the limits of our sample, this suggests that there are no unique digital divide barriers specific to cirrhosis.

Although descriptive studies have indicated that cognitive decline and episodic memory are barriers to both technology adoption and Internet use, two studies have found evidence suggesting other elements are involved [24, 26]. In addition to age and education, they found other

predictors of technology proficiency: sense of control, inductive reasoning, perceptual speed, and psychomotor speed. They hypothesized that these additional predictors could compensate for cognitive and memory issues [24, 26]. Similarly, a history of HE was not a significant predictor of either CPQ or MDPQ scores. Notably, these patients were on lactulose or rifaximin as per practice guidelines [34], and detailed cognitive testing was not carried out in the current study.

Patients with cirrhosis had positive perceptions and attitudes regarding video conferencing with healthcare professionals. For comparison, a 2016 study in England reported that only 50% of 270 adult patients attending one of three general practitioners' clinics were willing to use video consulting [35]. In this study, patients expected that videoconferencing should be confidential, it would be quick to learn, and easy to do once they received training. These same factors influenced the intention to use video calling for 256 adults (median age: 71 years) who were living independently at home [36]. In cirrhosis, e-health involving video calling must meet the design and usability needs across a broad age spectrum (20-80+ years).

Though patients were receptive to a virtual personalized health management program, there was variation in their preferences for program content and functional features such as motivational tips. This suggests that for any e-health tool to be successful, it needs to be customizable and offer flexible options for interaction with the user. In addition to adequate training, it was clear that patients also wanted to engage with the virtual program on terms that best suited their perceived needs and interests.

Strengths and Limitations

A study strength is that patients were recruited from three different clinic environments - a tertiary care outpatient liver clinic at an academic hospital, a liver transplant clinic and an outpatient clinic affiliated with an inner-city tertiary care hospital. This ensured that participants came from diverse socioeconomic backgrounds, residential locations, and health experiences thereby supporting the generalizability of the

results, except to those at the extremes of homelessness and poverty. Though the CPQ and MDPQ have been validated, they rely on self-reported skills and may not be reflective of a person's true ability. Though we did not have the infrastructure and resources to do so, a more direct evaluation of digital literacy proficiencies would be to watch a patient perform tasks in real-time. Commercial online proficiency tests are available but extensive customization of the proprietary software is required for research making them impractical [37]. As inclusion criteria required English language proficiency, the results cannot be generalized to non-English speakers.

Though we were able to explore the influence of many cirrhosis-related and general health-related factors on computing and mobile device proficiencies, it was beyond the scope of the study to explore the predictive characteristics that correlated with CPQ scores, such as inductive reasoning, perceptual speed, and psychomotor speed [24, 26]. Our rationale for selecting the CPQ and MDPQ was their specificity for evaluating computing and mobile device skills, ease of assessment, and currency in consideration of the rapid changes in digital technology and Internet behaviours.

In conclusion, we found that patients living with cirrhosis are ready for e-health a long as it is provided alongside adequate training and support. The recent successes of e-health suggest that it will no doubt persist beyond the current pandemic [38, 39]. Only by building upon past work and integrating useful frameworks (i.e., Technology Evaluation and Assessment Criteria for Health apps [40]) will e-health solutions effectively improve patient care and health outcomes. It is becoming apparent that society is rapidly moving into an era where e-health access and possessing a minimum of technology skills are becoming basic necessities rather than a luxury or lifestyle choice. For the cirrhosis population, results of this study show that e-health strategies offer promising opportunities to support patient management and healthcare.

Declarations

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