Reliability and Usability of the eChez-Soi In-home Telerehabilitation Platform: A New Internet-based Communication and Real-time Monitoring Software Solution Combined with Interactive Exercises

Results of a Longitudinal Pilot Study in Four Patients with Lung Cancer

Hélène Moffet[1,2], Didier Saey[1,3], Valérie Coats[3], Claude Vincent[1,2],
Fanny Choinière[2] and François Comeau[2]

[1]*Department of Rehabilitation, Faculty of Medicine, 1050 avenue de la Médecine, Université Laval, Québec (QC), Canada*
[2]*Center for Interdisciplinary Research in Rehabilitation and Social Integration,*
Institut de Réadaptation en Déficience Physique de Québec, 525 Boulevard Hamel, Québec (QC), Canada
[3]*Research Center of the Institut Universitaire de Cardiologie et Pneumologie de Québec,*
2725 Chemin Sainte-Foy, Québec (QC), Canada

Abstract: This longitudinal pilot study aims to describe the components and functionalities of the eChez-Soi home-based telerehabilitation platform, and present preliminary results on its technological reliability and usability. Four patients receiving chemotherapy treatments for lung cancer followed an 8 week home-based telerehabilitation program using the new eChez-Soi platform. All 60 planned sessions supervised by a clinician occurred with few technological problems. Only one session had to be rescheduled because of unresolved audiovisual communication problems. In 20 sessions, temporary problems were experienced, mostly related to the audiovisual signal (n=16), while few technical problems were associated with the sensors (n=1) and the interactive exercise software (n=1). The usability of the platform was very good, with an overall satisfaction rating of 4.63±0.43 (max. score=5) for all aspects evaluated, namely its dimension, safety, effectiveness, ease of use and game environment. These preliminary results support the reliability and usability of our new platform as a whole but highlight the challenges encountered in ensuring a stable audiovisual signal when delivering services via a standard home-based Internet connection.

1 INTRODUCTION

Implementation of home-based telerehabilitation is challenging. In combination with the development of user-friendly and economical platforms that provide quality audiovisual communication between clinician and client, it may also be necessary to allow real-time measurement of biomechanical and physiological parameters (Theodoros and Russell, 2008). This is particularly essential in prescribing safe, individually adapted exercises, as well as in progressively increasing the intensity of exercises to reach the goal of the intervention, especially in at-risk populations.

Moreover, there is growing scientific evidence that a gaming environment, and/or interactive exercises, adaptable to the needs of users promote better adherence to prescribed exercises (Baranowski et al., 2008, Plow et al., 2011). To our knowledge, however, few telerehabilitation platforms combining one or more of these functionalities have been developed; moreover, they were not widely implemented (Kairy et al., 2009). They were designed to meet specific rehabilitation needs of various populations and mainly to retrain balance and upper limb motor function of patients with neurodegenerative diseases, acquired brain injury or post-surgical deficits (Gonzalez-Fernandez et al., 2010, Parmanto et al., 2010, Gil-Gómez et al., 2011, Bento et al., 2012, Cikajlo et al., 2012, Kuusik et al., 2013, Krpic et al., 2013, Eguiluz-Perez and Garcia-Zapirain, 2014).

This pilot study provides preliminary results concerning the reliability and usability of the eChez-

Soi platform in the rehabilitation of patients with lung cancer. The eChez-soi platform is a new platform for home-based telerehabilitation which combines interactive exercises with real-time biomechanical and physiological parameter acquisition and transmission to the clinician during telerehabilitation sessions.

The aims of this study were: 1) to describe the components and functionalities of the eChez-Soi platform; 2) to describe the reliability of its technological components and its software solution designed for real-time acquisition, transmission and visualization of biomechanical and physiological signals, and for the creation of a gaming environment with interactive exercises; and 3) to collect four patients' perceptions of the usability of this new platform.

2 METHODS

This pilot study was conducted at the *Institut universitaire de cardiologie et de pneumologie de Québec (IUCPQ)*, in collaboration with the Centre for Interdisciplinary Research in Rehabilitation and Social Integration in Quebec City. The research protocol was approved by the institutional ethics committees. All participants provided written informed consent before enrollment in the study.

2.1 Participants

Potentially eligible patients (men or women), between 40 and 80 years of age, diagnosed with lung cancer and receiving chemotherapy treatments, were recruited from the *Clinique d'oncologie thoracique de l'IUCPQ*. Patients had to have an ECOG functional status (Scale of the Eastern Cooperative Oncology Group, see Oken et al., 1982) of 0 (Asymptomatic) or 1(Symptomatic but completely ambulatory); have a sufficient understanding of verbal and written instructions; and live in a geographic region served by a high speed Internet connection. Exclusion criteria were as follows: oxygen-pulsed saturation (SpO_2) <80% during the cardiopulmonary exercise test; contraindications to exercise testing according to the American Thoracic Society and American College of Chest Physicians Exercise Testing Guidelines (2003); cerebral or bone metastasis, a history of significant cardiovascular disease, hypertension, diabetes or musculoskeletal concerns that might limit their ability to perform active exercises; and severe psychiatric illness compromising adherence to the rehabilitation

training routine.

2.2 Study Design

Following their inclusion in the study and a baseline evaluation, a technician installed the eChez-Soi platform in the patient's home, and the eight-week telerehabilitation program was initiated. The proposed telerehabilitation program included strengthening exercises for upper and lower body and cardiovascular exercises, as well as recommendations to increase the daily physical activity level. Following the eight-week telerehabilitation program, participants were evaluated again and the telerehabilitation platform was uninstalled. Clinical tests were performed at both pre- and post-program evaluation times. Usability of the eChez-Soi platform was assessed during the post-program evaluation while its reliability was evaluated throughout the program delivery period (Figure 1).
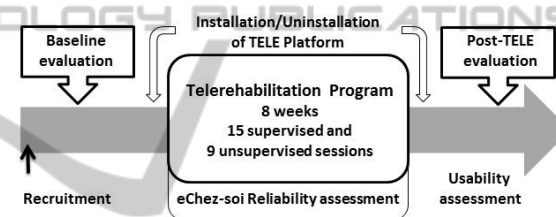

Figure 1: Time Line of the Study.

2.3 Telerehabilitation Platform

Through a unique software interface, the eChez-Soi telerehabilitation platform allows for the combination of the following three technological aspects: 1- continuous data acquisition and recording from commercial biometric sensors and other instruments used by patients during rehabilitation sessions; 2- continuous transmission of the collected data via the Internet to the clinician's computer, allowing the clinician to visualize the biomechanical and physiological parameters in real time; and 3- a challenging gaming environment with interactive exercises performed on musical rhythms using a dance mat and a Wii Balance Board. This gaming environment permits the clinician to create exercise routines adapted to the patient's condition and to export them remotely to the patient's platform. At the end of each routine, a score is provided to the patient, offering immediate feedback on their performance in order to encourage them to improve.

Biometric sensors used were: a wrist-worn pulse oximeter (Nonin WristOx$_2$™, Model 3150), wireless

wearable accelerometers (LEGSys™, BioSensics), and a Wii Balance Board (Nintendo® Wii Fit™), all using Bluetooth-based communication, as well as an Xbox Dance Mat connected by a USB cable. The following parameters were also collected regularly with these instruments: blood pressure (A&D Medical Blood Pressure Monitor), weight (Aria™ Wi-Fi Smart Scale) and daily physical activity (Fitbit Flex™). These sensors and devices were chosen because of their proven technology, ease of use, and portability, as well as the availability of Bluetooth or wireless communication.

The audiovisual communication between the patient and the clinician was supported by the videoconferencing solution Vidyo (Vidyo™ Desktop Software). This solution was chosen as a videoconferencing platform for its ease of deployment, its security, and its quality in a standard network environment.
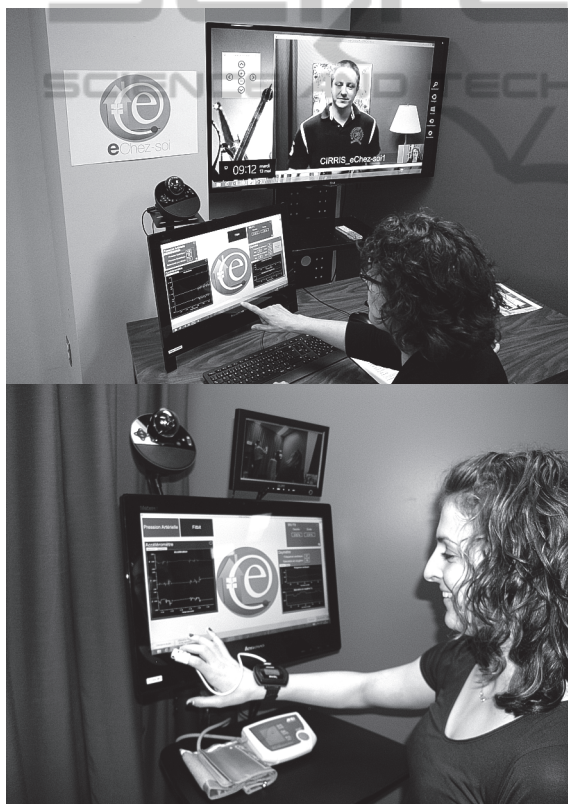

Figure 2: eChez-Soi Telerehabilitation Platform on the Clinician side (top) and Patient side (bottom).

The home-based telerehabilitation station for the patients includes an "all-in-one" computer with a touch screen and *Windows 8* friendly user interface, as well as a small external screen, a webcam, all sensors and instruments for biomechanical and physiological measurement and the software solution. The clinician's technological station includes an "all-in-one" computer with a touch screen and *Windows 8* friendly user interface, combined with a webcam and a large LCD screen for a good view of the patient (Figure 2).

2.4 Outcome Measures

2.4.1 Clinical Assessment

In order to provide a safe individualized exercise prescription, a complete clinical evaluation was made at baseline. It included assessments of pulmonary functions, body composition, muscle strength, functional exercise capacity and a screening for abnormal cardiovascular and pulmonary response to exercise. Clinical effects of the program are reported elsewhere.

2.4.2 Reliability and Usability Assessment

Reliability of the eChez-Soi platform was assessed by documenting the number, type, duration and transient or permanent nature of the technological problems encountered during supervised telerehabilitation sessions. In addition, recordings' reliability, with respect to the parameters observed in real time by the clinicians during prescribed routines of interactive exercises, was verified.

Usability was evaluated using a questionnaire adapted from the Québec User Evaluation of Satisfaction with Assistive Technology questionnaire (QUEST 2.0) that calculates both satisfaction scores for technological aspects and services, and the overall scores. It consists of 12 items rated on a scale from 1 to 5 (1: not satisfied at all to 5: very satisfied) (Demers et al., 2002). The QUEST has good construct validity (factorial: two dimensions), good to very good test-retest reliability (ICC = 0.82, 0.82 and 0.91) and good internal reliability (alpha: 0.76 to 0.82) (Demers et al., 1999, Demers et al., 2000). For the present project, five original technological aspects were preserved (items 1 to 5, Table 2) and seven new aspects (items 6 to 12, Table 2) were added.

2.5 Intervention

The planned intervention was an 8-week supervised home-based program (3sessions per week with an average duration of 75 minutes each). Over time, the ratio of supervised/unsupervised training sessions was progressively reduced from 3 supervised

sessions per week to one, in order to develop the patient's autonomy. In total, 15 supervised sessions and 9 unsupervised sessions were planned for a total of 24 exercise sessions.

Throughout the program, training modalities and intensity were adapted to the patient's condition. The training included: 1) warm-up and stretching exercises; 2) cardiorespiratory training and 3) resistance training of the upper and lower limbs. Exercises were executed using the Xbox Dance Mat and the Wii Balance Board via a game software environment developed for this purpose.

Before each supervised session, a short assessment was conducted to detect any significant changes in the participant's health condition. In addition, the participant's weight and blood pressure were measured using the platform instruments. Throughout the exercise session, participants used the pulse oximeter to assess the components of the physiological response (heart rate and oxyhemoglobin saturation). Data were transmitted in real time to the caregiver by the eChez-Soi platform. In order to ensure the security of the intervention, saturation should remain higher than 88% throughout the session.

3 RESULTS

3.1 Subject Characteristics

Four subjects were recruited between May and November 2014. Their personal and clinical characteristics are presented in Table 1.

Table 1: Subject Characteristics.

ID	Sex	Age (years)	BMI (Kg/m^2)	Stage	Tumor Type
01	Male	56	26.3	IV	ADK
02	Female	60	20.6	IIIA	ADK
03	Female	64	22.1	IV	ADK
04	Male	57	24.2	IV	ADK

*ADK: Adenocarcinoma

All patients received chemotherapy treatment during the intervention period, and two had concomitant radiotherapy during this period.

3.2 Compliance with the Intervention

All patients completed 100% of the supervised prescribed exercise sessions (15/15 sessions). No adverse event occurred during the entire intervention. Only one training session had to be postponed following the pre-training evaluation. (The patient had a high level of psychological distress and fatigue.) Also, the prescribed intensity had to be adjusted for one patient who showed a significant drop in oxyhemoglobin saturation during a supervised training session. The mean duration of supervised sessions was 67.5±12.9 minutes, and the total duration of all 61 sessions was 68.6 hours.

Given some familiarity with the telerehabilitation platform, due to its previous use in some supervised sessions, all four patients were able to easily use it during unsupervised sessions, following brief instructions from the clinician.

3.3 Reliability of eChez-Soi Platform

3.3.1 Reliability of the Technology

Of the 60 sessions of telerehabilitation offered to the four patients, only one session had to be delayed due to an inability to establish audiovisual communication between the patient and the clinician. Three other sessions were cut short because of technical problems.

Temporary problems (n=20) were observed and resolved during 13 sessions. Most of these problems were related to audiovisual communication (n=16). The other difficulties were due to the poor functioning of a sensor (n=1, pulse oximeter, and n=1, Wii Balance) or the software solution (synchronization of a sensor, n=1; interactive exercises, n=1). 186 minutes in total (4.5% of the entire duration of the sessions) were used to resolve these temporary problems. Half of the sessions with technical problem and the time spent resolving them occurred during the follow-up care of the first patient in this study (patient 01; 7 sessions with temporary technical problems and 91 minutes spent resolving them).

3.3.2 Real-time Measurements and Recordings

Data from the pulse oximeter (heart rate and oxyhemoglobin saturation), the accelerometers and the Wii Balance were recorded for all interactive exercise routines (n=331) performed during the 61 supervised sessions without problems, with the exception of 24 routines (7% of the routines) where data from at least one sensor, mainly the oximeter (n=10), were not recorded.

Reliability and Usability of the eChez-Soi In-home Telerehabilitation Platform: A New Internet-based Communication and
Real-time Monitoring Software Solution Combined with Interactive Exercises - Results of a Longitudinal Pilot Study in
Four Patients with Lung Cancer

3.4 Usability of eChez-Soi Platform

All four patients were quite satisfied (score of 4) or very satisfied (score of 5) with all aspects of the home-based telerehabilitation platform, for a mean score of 4.63 (Table 2). No 1 to 3 scores were reported for any of the assessed items. Ease of use and effectiveness of the telerehabilitation platform, and audiovisual communication between the client and the clinician were identified by the patients as the three most important elements related to the usability of the platform.

Table 2: Usability of the Telerehabilitation Platform (TP) measured with an adaptation of the Quebec User Evaluation of Satisfaction with assistive technology.[1.]

Item	How satisfied are you with the…	Score[1]
1.	dimension of your TP?	4.75 (0.50)
2.	safety of your TP?	4.75 (0.50)
3.	durability of your TP?	4.50 (0.58)
4.	* ease of use of your TP?	4.50 (0.58)
5.	* effectiveness of your TP?	4.75 (0.50)
6.	biometric sensors of the TP for taking data in real time (e.g. Nonin oximeter)?	4.25 (0.50)
7.	devices used by the patient for reading automatic data (e.g. Fitbit Flex)?	4.75 (0.50)
8.	visualization in real time of biometric data collected by sensors on the client workstation and transferred to the clinician's computer?	4.75 (0.50)
9.	game environment, enabling customers to perform exercises tailored to their condition?	4.75 (0.50)
10.	* audiovisual communication between the client and the clinician?	4.75 (0.50)
11.	touch screen and user-friendly interface (Windows 8)?	4.50 (0.58)
12.	illustrated procedures accompanying the user of the TP?	4.50 (0.58)
	Overall score (SD):	4.63 (0.43)

[1] Mean QUEST score (standard deviation) for the 4 patients (1: not satisfied at all; 2: not very satisfied; 3: more or less satisfied; 4: quite satisfied; 5: very satisfied)
* 3 items reported as most important.

4 CONCLUSIONS

These preliminary results support the technical reliability and usability of the eChez-soi telerehabilitation platform. During the entire period of this pilot study, relatively few technical problems were experienced by the users (4.5% of the time). Almost all technical difficulties were transient and addressed rapidly within the same session. Lastly, most of the problems (50%) were experienced by the first participant, thus demonstrating our capacity to prevent the repetition of previous technical problems. However, some problems with the audiovisual connection or signal quality were experienced by all participants, thereby illustrating the challenges of delivering services at home through a standard home-based Internet connection.

All users were satisfied with the different aspects of the new platform, with the highest score (4.75/5) being found for dimension, safety, effectiveness, devices, visualization in real time of biometric data collected by sensors, the game environment and the audiovisual communication between the client and the clinician, even though most of the technical problems (80%) were related to this last aspect.

Future studies are needed to confirm the present results obtained with only four patients, although the platform was tested during a significant number of sessions and periods of time (61 sessions lasting 68 hours). This platform's potential should also be tested in other contexts and populations.

ACKNOWLEDGEMENTS

REFERENCES

American Thoracic Society; American College of Chest, Physicians. 2003. ATS/ACCP Statement on cardiopulmonary exercise testing. *Am J Respir Crit Care Med,* 167, 211-77.

Baranowski, T., Buday, R., Thompson, D.I., Baranowski, J. 2008. Playing for real: video games and stories for health-related behavior change. *Am J Prev Med*, 34, 74-82.

Bento, V. F., Cruz, V. T., Ribeiro, D. D., Colunas, M. M., Cunha, J. P. 2012. The SWORD tele-rehabilitation system. *Stud Health Technol Inform,* 177, 76-81.

Cikajlo, I., Rudolf, M., Goljar, N., Burger, H., Matjacic, Z.

2012. Telerehabilitation using virtual reality task can improve balance in patients with stroke. *Disabil Rehabil,* 34(1), 13-18.

Demers, L., Ska, B., Weiss-Lambrou, R. 1999. Stability and reproducibility of the Quebec User Evaluation of Satisfaction with Assistive Technologie (QUEST). *J Rehabil Outcomes Measures*, 3, 42-52.

Demers, L., Weiss-Lambrou, R., Ska, B. 2000. Item analysis of the Quebec user evaluation of satisfaction with assistive technology (QUEST). *Assist Technol,* 12(2), 96-105.

Demers, L., Weiss-Lambrou, R., Ska, B. 2002. The Quebec user evaluation of satisfaction with assistive technology (QUEST 2.0): An overview and recent progress. *Technol Disabil*, 14, 101-5.

Eguiluz-Perez, G., & Garcia-Zapirain, B. 2014. Comprehensive verticality analysis and web-based rehabilitation system for people with multiple sclerosis with supervised medical monitoring. *Biomed Mater Eng,* 24(6), 3493-3502.

Gil-Gómez, J.A., Lloréns, R., Alcñiz, M., Colomer, C. 2011. Effectiveness of a Wii balance board-based system (eBaViR) for balance rehabilitation: A pilot randomized clinical trial in patients with acquired brain injury. *J Neuroeng Rehabil,* 8, 30.

Gonzalez-Fernandez, M., Gil-Gomez, J. A., Alcaniz, M., Noe, E., Colomer, C. 2010. eBaViR, easy balance virtual rehabilitation system: a study with patients. *Stud Health Technol Inform,* 154, 61-66.

Kairy, D., Lehoux, P., Vincent, C., Visintin, M. 2009. A systematic review of clinical outcomes, clinical process, healthcare utilization and costs associated with telerehabilitation. *Disabil Rehabil,* 31, 427-47.

Krpic, A., Savanovic, A., & Cikajlo, I. 2013. Telerehabilitation: remote multimedia-supported assistance and mobile monitoring of balance training outcomes can facilitate the clinical staff's effort. *Int J Rehabil Res,* 36(2), 162-171.

Kuusik, A., Sarna, K., & Reilent, E. 2013. Home rehabilitation system supported by the safety model. *Stud Health Technol Inform,* 189, 145-151.

Oken, M.M., Creech, R.H., Tormey, D.C., Horton, J., Davis, T.E., McFadden, E.T., Carbone, P.P. 1982. Toxicity and response criteria of the Eastern Cooperative Oncology Group. *Am J Clin Oncol,* 5, 649-655.

Parmato, B., Saptono, A., Pramana, G., Pulantara, W., Schein, R. M., Schmeler, M. R., Mccue, M. P., Brienza, D. M. 2010. VISYTER: versatile and integrated system for telerehabilitation. *Telemed J E Health,* 16, 939-44.

Plow, M.A., McDaniel, C., Linder, S., Alberts, J.L. 2011. A scoping review of exergaming for adults with systemic disabling conditions. *J Bioengineer Biomedical Sci*, S1-002.

Theodoros, D. & Russell, T. 2008. Telerehabilitation: current perspectives. *Stud Health Technol Inform,* 131, 191-209.