34th Annual International Conference of the IEEE EMBS
San Diego, California USA, 28 August - 1 September, 2012

Impact of Physical Telerehabilitation on Functional Outcomes in Seniors with Mobility Limitations*

Joseph Finkelstein, Jeffrey Wood, and Eunme Cha

Abstract— **The goal of this project was to objectively assess potential impact of home-based physical telerehabilitation program on functional outcomes in seniors with mobility limitations. Nine consecutive seniors with mobility limitations were enrolled into a 12-week physical telerehabilitation program. At the end of the program, the mean time that patients took to walk 25 feet decreased from 13.5 to 10.6 seconds, and the mean distance that patients walked in 6 minutes improved from 722.4 to 805.7 feet. The Berg Balance Score score also increased from 36.6 to 41.7 over the 12-week period. All changes were statistically significant ($p<0.05$). Patients demonstrated very high acceptance of the home-based program.**

I. Introduction

Physical exercise therapy has been shown to improve functional outcomes in seniors with different chronic conditions such as diabetes as well as in seniors after hip arthroplasty [1-3]. Physical exercise therapy in elderly patients had a positive effect on quality of life and activities of daily living [4]. Individualized in-home rehabilitation has also been shown to increase self-efficacy in elderly patients [5]. The potential of in-home computer and telecommunication technologies supporting patient self-management has been well recognized to have significant potential in improving the quality of chronic care [6] however limited data exist on impact of physical telerehabilitation in seniors. The goal of this project was to objectively assess potential impact of home-based physical telerehabilitation program on functional outcomes in seniors with mobility limitations.

We developed a Home Automated Telemanagement (HAT) rehabilitation system for in-home tellerehabilitation of elderly patients. The HAT system was designed to guide patients through in-home physical therapy sessions and allow for remote patient monitoring by a physical therapy team. A 12-week study was conducted to assess the feasibility and patient acceptance of the system.

II. Methods

A. System Design

The conceptual design of the Home Automated Telemanagement rehabilitation system is based on the principles of patient-centered care delivery model [7]. The HAT system supports the major components of this model including patient self-care, individualized treatment plan, guideline-concordant decision support, comprehensive patient provider communication, and multidisciplinary care coordination [8]. Using this model, the HAT system has been successfully implemented and tested in various health conditions including asthma, ulcerative colitis, and inflammatory bowel disorder [9-13]. Previous HAT applications have utilized laptops, PDA, IVR, and cell phones for patient home units [15-18].

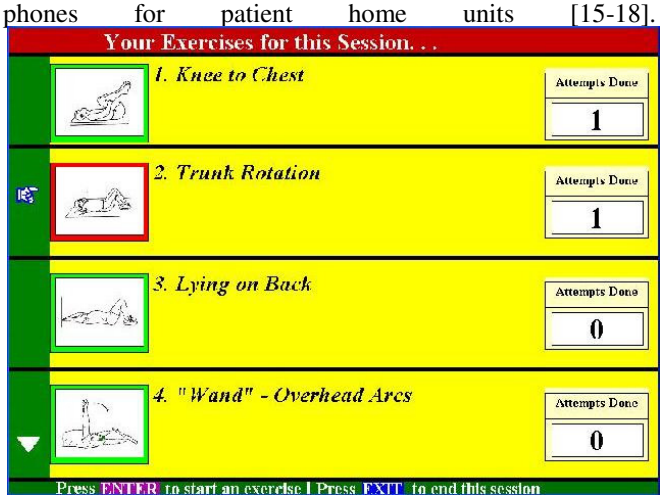

Figure 1. Home unit interface: Physical Therapy Plan.

The HAT system consists of a patient home unit, a clinician portal and the HAT server. The HAT patient home unit software was developed for use on low cost netbooks and touch-screen tablet PC. The patient interface was designed to be as easy to use and simple as possible while presenting clear exercise instruction in multiple ways to the patient.

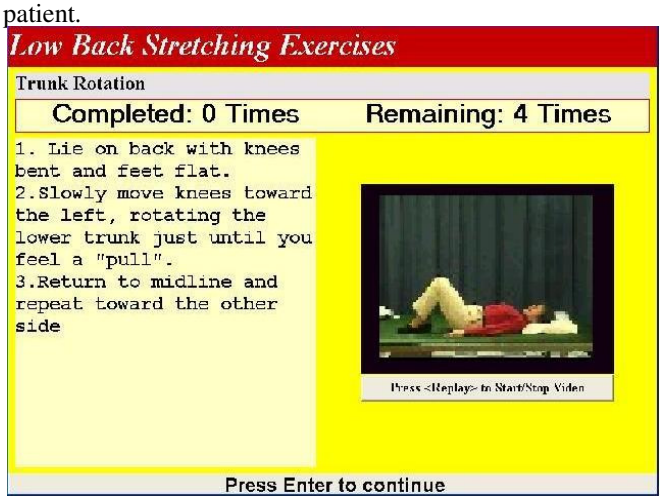

Figure 2. Home unit interface: Exercise directions.

*Research supported by Secunda Family Foundation

J. Finkelstein is with the Chronic Disease Informatics Program, Johns Hopkins University School of Medicine, Baltimore, Maryland, 21224, USA (e-mail: jfinkel9@jhmi.edu).

J. Wood is with the Chronic Disease Informatics Program, Johns Hopkins University School of Medicine, Baltimore, Maryland, 21224, USA (e-mail: jwood27@jhmi.edu).

E. Cha is with the Chronic Disease Informatics Program, Johns Hopkins University School of Medicine, Baltimore, Maryland, 21224, USA (e-mail: echa5@jhu.edu).

The clinician web portal can be run on any web-enabled device and was developed using the Microsoft .NET framework. It is able to run on any HTML enabled browser and assists physical therapy team in setting up individualized physical therapy plan, patient monitoring and patient-provider communication. The HAT server uses Internet Information Services to host the clinician web portal and stores patient data in a SQL Server database.

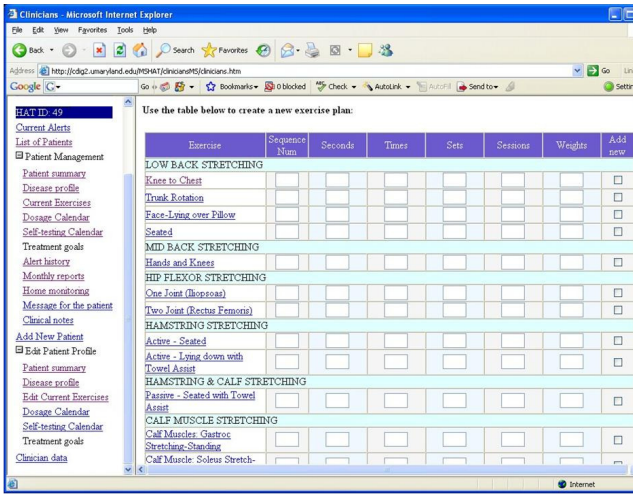

Figure 3. HAT clinician website: Exercise prescription pad.

The HAT patient home unit (Figure 1) can communicate with the HAT server through a patient's landline phone, wireless or internet connection. The HAT home unit guides the patient to complete a daily individualized exercise program and symptom diary. The interface is navigated using the labeled arrow and ENTER keys while all other keys are disabled to prevent any unwanted input. The patients use a wireless keypad to navigate the home unit remotely while carrying out an exercise program. When completing the daily exercise diary the patient is presented with their individualized exercise program and can choose which exercise they would like to attempt. The patient is then given exercise instructions through images, written instructions, and video clips of a physical therapist explaining and demonstrating the exercise (Figure 2). Patients may attempt the exercise, then input the number of times it was completed and report if they had any difficulty completing it. The results of the exercise diary are immediately sent to our server and can be accessed through the clinician portal.

The clinician portal can be securely accessed by care providers and contains all information from patient's exercise sessions and symptom diary. Individualized patient alerts can be set for physicians based upon exercise diary and symptom diary results. Clinicians can view patient exercise sessions, make clinical notes, edit patient exercise plans, and send messages to the patient's home unit (Figure 3). The HAT server can be setup to generate individualized alerts to the physical therapy team based on patient exercise performance and daily symptom diary.

TABLE I. DEMOGRAPHICS

Parameter	Value	Parameter	Value
Number of subjects	9	Number of subjects	9
Mean age	53.3 ± 2.5	Internet Use	
Sex		Once a month or less	0.0 (0)
Male	22.2 (2)	Once a week	11.1 (1)
Female	77.8 (7)	Once a day	88.9 (8)
Race		Computer use at work / school	
White	88.9 (8)	Never	55.6 (5)
African American	11.1 (1)	Once a month or less	0.0 (0)
Income level		Once a week	0.0 (0)
<20K	0.0 (0)	Once a day	44.4 (4)
20K-30K	22.2 (2)	Computer use at home	
30K-40K	11.1 (1)	Never	0.0 (0)
40K-50K	11.1 (1)	Once a month or less	0.0 (0)
50K-70K	22.2 (2)	Once a week	0.0 (0)
70K-90K	0.0 (0)	Once a day	100.0 (9)
>90K	22.2 (2)	ATM use	
Refused to answer	11.1 (1)	Never	44.4 (4)
Mean education (years)	15.6 ± 1.9	Once a month or less	44.4 (4)
Job		None	0.0 (0)
None	88.9 (8)	Very limited	0.0 (0)
Temporary/Part-time	11.1 (1)	Good	55.6 (5)
Full time	0.0 (0)	Excellent	44.4 (4)
Note: Values expressed as mean ± SD or number (percent).			

B. Study Sample

We recruited 9 consecutive patients from outpatient sites in Greater Baltimore area. Subjects were eligible to participate in the study if they were aged 50 or older and had

mobility limitations. Subjects were ineligible if they had (1) musculoskeletal diagnoses or unstable cardiovascular, respiratory, metabolic, or other conditions that would interfere with this study. The patients were also required to have a working telephone line in their home for communication with the study team. Level of computer experience was not considered for patient enrollment. The baseline characteristics of the study sample are presented in Table I.

Of the 9 consecutive senior patients, 22 percent (2) were males and 78 percent (7) were females. The mean age was 53 ± 3, and education (in years) was 16 ± 2. (Values are expressed as mean ± standard deviation unless otherwise indicated.) Of the enrolled patients, 88.9 percent (8) claimed that they used the internet once a day and 100 percent (9) stated they used the computer once a day at home. All (9) of the patients self-reported that their English proficiency was excellent or good.

C. Intervention

Nine senior (>50yrs) patients with mobility limitations participated in a pilot study of the HAT rehabilitation system. First, a comprehensive baseline evaluation of the patient was conducted by a physical therapist. According to the physical therapist evaluation results, each patient was assigned an individualized physical therapy exercise program and trained in person by a therapist on how to complete each exercise. The exercise program was then prescribed on the HAT clinician portal. Once it was prescribed on the clinician portal, the exercise program was uploaded to the patient home unit and each patient was given an individualized HAT home unit netbook and trained on how to use it during the home installation visit. Results from the exercise sessions were immediately sent to the HAT server where they could be analyzed and tracked by the patient's physical therapist through the HAT clinician portal.

The physical therapist could also contact the patient by phone to answer any patient questions or advise the patient on their physical therapy routine. By logging on to the clinician portal the physical therapist could make changes to the patient's exercise plan and upload it to the patient home unit.

The physical therapist recommended to the patients that the individualized exercise program be completed over the course of the day to avoid over exertion and advised that patients adhere to a level that was "difficult but not a struggle." Technical and clinical support was available to all patients by telephone or email, but only a few participants had occasional problems or concerns requiring changes. Following the 6-week reevaluation each patient's exercise program was updated and revised.

III. RESULTS

Patients were evaluated at baseline and 12 weeks. Each evaluation consisted of a functional status evaluation performed by a physical therapist in an outpatient clinic and followed by a patient home visit, during which study questionnaires were administered.

TABLE II. STUDY RESULTS

Baseline – 12th week	**N**	**Mean (at Baseline)**	**Mean (at the 12th week)**	***p*-value†**
T25-FW (sec.)				
#1 (The first attempt)	9	13.8 ± 8.7	10.8 ± 4.5	0.02*
#2 (The second attempt)	9	13.2 ± 8.6	10.4 ± 4.5	0.05*
Average of #1 and #2	9	13.5 ± 8.6	10.6 ± 4.5	0.04*
Z score‡	9	0.3 ± 0.8	0.1 ± 0.4	0.04*
6-min walk (feet)	9	722.4 ± 512.7	805.7 ± 485.8	0.01*
Berg Balance Scale	9	36.6 ± 12.1	41.7 ± 11.1	0.004*
MOS Patient Adherence Measure	9	4.2 ± 0.8	4.4 ± 0.9	0.5
CSQ-8	9	----	29.8 ± 2.2	----
Age >=50				
Note: CSQ-8 was measured at the exit interview only.				
†Wilcoxon Signed Rank Test				
‡ Z score = (Mean T25W – 9.5353) / 11.4058				
* *p*-value <0.05				

The clinical impact of the HAT system was measured in three major domains: (1) functional status, (2) patient quality of life (QOL), and (3) behavioral and psychosocial domain. The primary outcome was improvement in scores assessing patient functional status. The functional status was assessed with a timed 25-foot walk (T25FW), 6-minute walk, Berg Balance Scale (BBS), and Modified Ashworth Scale (MAS). For the T25FW, the patient was instructed to walk 25 feet as fast as safely possible. Then the patient repeated the task by walking back to the starting point. If necessary, assistive devices could be used. We measured the amount of time (in seconds) that the patient took to walk 25 feet. We performed

a similar task for the 6-minute walk by measuring how far (in feet) the patient walked within the 6 minute period. The BBS, which consists of 14 movements common in daily life, was designed to measure balance in a clinical setting. The patient was asked to sustain a given position for a specific time. Points were deducted if the patient did not fulfill the time or distance requirements, touched an external support, or received assistance from the examiner. Each item ranged from 0 to 5. The MAS measures the resistance encountered during passive muscle stretching. Its scale ranges from 0 to 4:

- 0 = no increase in muscle tone.
- 1 = slight increase in tone with a catch and release.
- 1+ = slight increase in tone, manifested by a catch, followed by minimal resistance.
- 2 = marked increase in tone.
- 3 = considerable increase in tone.
- 4 = rigid in flexion or extension.

Other secondary outcomes from behavioral and psychosocial domain included Medical Outcomes Study (MOS) Patient Adherence Measure, and 8-item Client Satisfaction Questionnaire (CSQ-8). We used MOS Patient Adherence Measure to assess a patient's tendency to adhere to a doctor's recommendations during the past 4 weeks and CSQ-8 to measure client satisfaction with the service. Results are shown in Table II.

The T25FW, 6-minute walk, and BBS scores improved significantly from baseline to the 12-week follow-up. The mean time that patients took to walk 25 feet decreased from 13.5 to 10.6 seconds, and the mean distance that patients walked in 6 minutes improved from 722.4 to 805.7 feet. The BBS score also increased from 36.6 to 41.7 over the 12-week period. MAS improved in quadriceps left and right: for quadriceps left, the percentage of patients who scored 0 increased from 44.4 to 66.7 percent, and for quadriceps right, the percentage increased from 44.4 to 66.7 percent as shown in Table III.

TABLE III. MODIFIED ASHWORTH SCALE

		0	1	1+	2	3	4	*P*-value†
		%						
Quadriceps Left	**Baseline**	**44.4**	**22.2**	**11.2**	**22.2**	**0.0**	**0.0**	
	12th week	**66.7**	**0.0**	**11.1**	**22.2**	**0.0**	**0.0**	**0.008**
Quadriceps Right	**Baseline**	**44.4**	**11.2**	**44.4**	**0.0**	**0.0**	**0.0**	
	12th week	**66.7**	**11.1**	**22.2**	**0.0**	**0.0**	**0.0**	**0.2**

Patients were also asked to complete an attitudinal survey to measure their overall feelings towards the HAT system. The survey measured any difficulty the patients had using the home unit and their acceptance of computer features, such as color on the screen, text size, audiovisual content, keyboard/mouse, and educational program. Overall response to the system was positive. 88.9% of patients reported that the system was "Not complicated at all" while 11.1% found it "Slightly complicated". 66.7% had no difficulties reading the text on the screen while 33.3% very rarely had trouble. All patients liked the audiovisual content provided by the system, with 66.7% saying "Certainly yes", 22.2% said "To a large extent" and 11.1% said "To some extent." 77.8% of patients said they would definitely advise other patients to use the system while 22.2% said they would maybe advise other patients to use the system. Patient responses are shown in Table IV.

IV. CONCLUSIONS

Home-based physical telerehabilitation is feasible with seniors, and it can potentially improve patient functional status significantly. The participants of the study demonstrated a very high level of support for the home-based physical telerehabilitation program and further studies are warranted. Mobile computing [18], wireless sensors [19], and gaming platforms [20] should be considered to enhance future physical telerehabilitation systems for seniors.

TABLE IV. ATTITUDINAL SURVEY

	Score, %			
Questions	**1**	**2**	**3**	**4**
1. How complicated was it to use the computer?				
Very complicated	**0.0**			
Moderately complicated		**0.0**		
Slightly complicated			**11.1**	
Not complicated at all				**88.9**
2. Did you have any difficulty in moving from one screen to another?				
Not at all	**66.7**			
Very rarely		**11.1**		
Frequently			**22.2**	
All the time				**0.0**
3. How difficult was it to use the keyboard/mouse?				
Very difficult	**0.0**			

Moderately difficult		**0.0**		
Slightly difficult			**33.3**	
Not difficult at all				**66.7**
4. Did you have any difficulties in reading text from the computer screen?				
Not at all	**66.7**			
Very rarely		**33.3**		
Frequently			**0.0**	
All the time				**0.0**
5. Was the size of the text presented on the screen sufficient?				
Fully sufficient	**88.9**			
Sufficient almost all the time		**11.1**		
Sufficient some of the time			**0.0**	
Not sufficient at all				**0.0**
6. Did you like the colors used on the computer screen?				
Certainly yes	**55.6**			
To a large extent		**33.3**		
To some extent			**11.1**	
No				**0.0**
7. Did you like the audiovisual content provided by the computer?				
Certainly yes	**66.7**			
To a large extent		**22.2**		
To some extent			**11.1**	
No				**0.0**
8. Did you get all the necessary information about using the computer during initial practice session?				
All information	**77.8**			
Almost all information		**22.2**		
Partial information			**0.0**	
Very limited information				**0.0**
9. Did you come across any unknown words which were not explained by the computer?				
Very significant	**0.0**			
Considerable		**0.0**		
A few			**0.0**	
None				**100.0**
10. How difficult were the sentences used in the educational materials?				
Very difficult	**0.0**			
Moderately difficult		**0.0**		
Slightly difficult			**0.0**	
Not difficult at all				**100.0**
11. How much new information did you get using the computer?				
Very significant amount	**22.2**			
Considerable		**33.3**		
Little			**44.5**	
Very little				**0.0**
12. Did you get any feedback from computer about your learning progress?				
All the time	**66.7**			
Occasionally		**11.1**		
Very rarely			**22.2**	
Never				**0.0**
13. How frequently did you find the information confusing?				
Very frequently	**0.0**			
Occasionally		**11.1**		
Very rarely			**33.3**	
Never				**55.6**
14. How frequently did you find educational contents difficult to understand?				
Very frequently	**0.0**			

Occasionally		**0.0**		
Very rarely			**22.2**	
Never				**77.8**
15. Did you have to wait for new information to come up on the screen?				
All the time	**0.0**			
Occasionally		**11.1**		
Very rarely			**33.3**	
Never				**55.6**
16. Would you like to use this educational program in the future?				
Certainly yes	**55.6**			
Maybe		**22.2**		
Unlikely			**22.2**	
No				**0.0**
17. Would you advise other patients to use this educational program?				
Certainly yes	**77.8**			
Maybe		**22.2**		
Unlikely			**0.0**	
No				**0.0**
18. Overall how would you grade this educational program?				
Needs serious improvement	**0.0**			
Needs some improvement		**22.2**		
Good			**44.5**	
Excellent				**33.3**

REFERENCES

[1] Oosting E, Jans MP, Dronkers JJ, Naber RH, Dronkers-Landman CM, Appelman-deVries SM, van Meeteren NL. Preoperative Home-Based Physical Therapy Versus Usual Care to Improve Functional Health of Frail Older Adults Scheduled for Elective Total Hip Arthroplasty: A Pilot Randomized Controlled Trial. Arch Phys Med Rehabil. 2012;93(4):610-6. PMID: 22365481.

[2] Juliano K, Edwards D, Spinello D, Capizzano Y, Epelman E, Kalowitz J, Lempel A, Ghomrawi H. Initiating physical therapy on the day of surgery decreases length of stay without compromising functional outcomes following total hip arthroplasty. HSS J. 2011;7(1):16-20. PMID: 22294953.

[3] Castro-Sánchez AM, Matarán-Peñarrocha GA, Feriche-Fernández-Castanys B, Fernández-Sola C, Sánchez-Labraca N, Moreno-Lorenzo C. A Program of 3 Physical Therapy Modalities Improves Peripheral Arterial Disease in Diabetes Type 2 Patients: A Randomized Controlled Trial. J Cardiovasc Nurs. 2012 Jan 4. [Epub ahead of print] PMID: 22222177.

[4] de Vries NM, van Ravensberg CD, Hobbelen JS, Olde Rikkert MG, Staal JB, Nijhuis-van der Sanden MW. Effects of physical exercise therapy on mobility, physical functioning, physical activity and quality of life in community-dwelling older adults with impaired mobility, physical disability and/or multi-morbidity: A meta-analysis. Ageing Res Rev. 2012;11(1):136-49. PMID: 22101330.

[5] Sanford JA, Griffiths PC, Richardson P, Hargraves K, Butterfield T, Hoenig H. The effects of in-home rehabilitation on task self-efficacy in mobility-impaired adults: A randomized clinical trial. J Am Geriatr Soc. 2006;54(11):1641-8. PMID: 17087689.

[6] Finkelstein J, Friedman RH. Potential role of telecommunication technologies in the management of chronic health conditions. Dis Manage Health Outcomes 2000;8(2):57-63.

[7] Finkelstein J, Barr MS, Kothari PP, Nace DK, Quinn M. Patient-centered medical home cyberinfrastructure: current and future landscape. Am J Prev Med. 2011;40(5 Suppl 2):S225-33. PMID:21521598.

[8] Finkelstein J, Cha E. Hypertension telemanagement in blacks. Circ Cardiovasc Qual Outcomes. 2009;2(3):272-8. PMID:20031848.

[9] Finkelstein J, Hripcsak G, Cabrera M. Telematic system for monitoring of asthma severity in patients' homes. Stud Health Technol Inform. 1998;52 Pt 1:272-6. PMID:10384460.

[10] Finkelstein J, Khare R, Ansell J. Feasibility and patients' acceptance of Home Automated Telemanagement of oral anticoagulation therapy. AMIA Annu Symp Proc. 2003:230-4. PMID:14728168.

[11] Cross R, Cheevers N, Finkelstein J. Home Telemanagement for Patients with Ulcerative Colitis (UC HAT). Digestive Diseases and Sciences 2009;54(11):2463-72. PMID:19104937

[12] Finkelstein J, Wood J. Design and implementation of Home Automated Telemanagement system for patients with multiple sclerosis. Conf Proc IEEE Eng Med Biol Soc. 2009;2009:6091-4. PMID:19965257.

[13] Cross RK, Arora M, Finkelstein J. Acceptance of telemanagement is high in patients with Inflammatory Bowel Disorder. Journal of Clinical Gastroenterology 2006;40:200-8. PMID:16633120.

[14] Finkelstein J, Khare R, Vora D. Home Automated Telemanagement (HAT) system to facilitate self-care of patients with chronic diseases. Journal of Systemics, Cybernetics and Informatics 2003;1(3):78-82.

[15] Farzanfar R, Finkelstein J, Friedman RH. Testing the usability of two automated home-based patient management systems. J Medical Systems 2004; 28(2): 143-153. PMID:15195845.

[16] Samal L, Hutton HE, Erbelding EJ, Brandon ES, Finkelstein J, Chander G. Digital divide: variation in internet and cellular phone use among women attending an urban sexually transmitted infections clinic. J Urban Health. 2010;87(1):122-8. PMID:19941085.

[17] Wood J, Yablochnikov I, Finkelstein J. Interactive asthma learning system utilizing a mobile phone platform. AMIA Annu Symp Proc. 2008 Nov 6:1181. PMID:18999060.

[18] Skinner C, Finkelstein J. Using cell phones for chronic disease prevention and management. AMIA Annu Symp Proc. 2008 Nov 6:1137. PMID:18999018.

[19] Jeong IC, Finkelstein J. Computer-assisted upper extremity training using interactive biking exercise (iBikE) platform. Conf Proc IEEE Eng Med Biol Soc. 2012;2012:in press.

[20] Finkelstein J, Wood J. Implementing home telemanagement of congestive heart failure using Xbox gaming platform. Conf Proc IEEE Eng Med Biol Soc. 2011;2011:3158-63. PMID:22255010.