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Interactive Resistance Chair to Promote Strengthening Exercise in Older Adults

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Abstract. We developed a strengthening exercise support system which can be remotely managed and clinically supervised via internet. Older adults may potentially benefit from such an exercise system however functionality of this system requires validation before commencement of field studies in older adults. The aim of this study was to introduce and assess validity of a prototype telerehabilitation system supporting computer-assisted home-based strengthening exercise. The system included a resistance chair with a set of movement and physiologic sensors. Real-time feedback on exercise performance was displayed on a touch screen dashboard. Personalized exercise parameters were managed by a rehabilitation team via a designated telerehabilitation site. Assessment of the system demonstrated sufficient validity in real-time identification of exercise performance and cardiovascular parameters. We concluded that the interactive resistance chair has a potential in promoting strengthening exercise and it is warranted for further evaluation in community dwelling older adults.

Keywords. Personal health systems, Strengthening exercise, Telerehabilitation, Self-management

Introduction

Previous studies have shown that the strengthening exercise programs are effective means to improve functional performance in older adults and to reduce morbidity and mortality in people with multiple chronic conditions [1-3]. Home-based telemedicine solutions can potentially facilitate exercise promotion in older adults however more systematic research is needed in this area. High acceptance of home-based telemanagement applications by older adults with various chronic health conditions has been demonstrated in our previous studies [4-6]. One of the major lessons learnt from this group of patients was particular interest in supervised home-based telerehabilitation systems supporting regular exercise [7]. To address this interest, we developed a strengthening exercise support system which can be remotely managed and clinically supervised via internet. Older adults may potentially benefit from such an exercise system however functionality of this system requires validation before commencement of field studies in older adults.

The aim of this study was to introduce and assess validity of a prototype telerehabilitation system supporting computer-assisted home-based strengthening exercise.

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1. System

Our ultimate objective is to build a distributed web-based system which would facilitate comprehensive geriatric telerehabilitation by supporting physical, cognitive and occupational components of personalized goal-oriented rehabilitation program.

1.1. System Design

An interactive strengthening exercise system is an extension of Home Automated Telemanagement system which was previously described [7-8]. The HAT system follows Wagner's chronic care model [9]. The HAT system supports the major components of this model including patient self-care, tailored education and counseling, individualized treatment plan, guideline-concordant decision support, comprehensive patient provider communication, and multidisciplinary care coordination [7-9].

The strengthening exercise system consists of a clinician unit, HAT server, and a home unit as shown in Figure 1. The clinician unit is designed to access the patient data and history; to adjust patient-specific parameters related to the decision support, patient exercise plan, and patient prescription; to review alerts; and to exchange messages between clinicians and patients. The HAT server consists of a web server, HAT database, and HAT decision support module. The server supports a secure access to all data generated by clinicians and patients via internet and stored in the HAT database. The decision support module analyses all data traffic and generates alerts according to individually defined thresholds as previously described [7]. The home unit supports real-time data transmission between the server and the patient unit. The home telerehabilitation unit consists of a touch screen tablet that communicates with the remote server via TCP/IP protocol. It collects physical exercise information from magnetic sensors (3144, Allegro Microsystems Inc., USA) and a blood oxygen

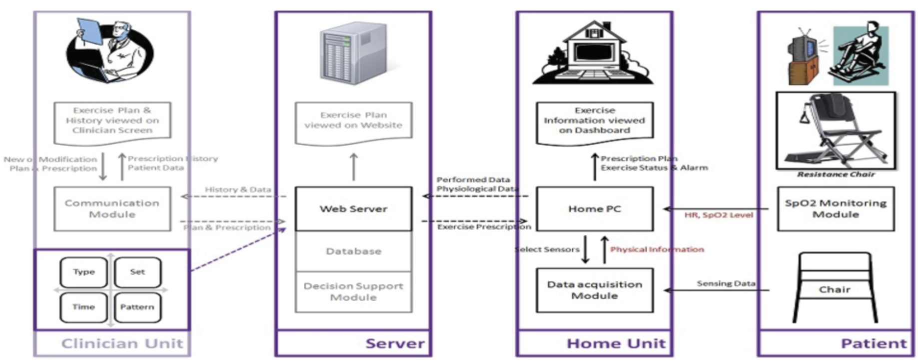

Figure 1. The strengthening exercise system design.

Figure 2. The strengthening exercise program dashboards.

saturation (SpO2) module (OEM III Evaluation Kit, Nonin Medical Inc., USA) to monitor heart rate (HR) and SpO2 for exercise efficacy and safety. The design of the home unit supports flexible exercise prescription and remote control of exercise settings by a comprehensive rehabilitation team, automated exercise records, real-time monitoring of patient progress towards recommended patient-specific exercise goals, and generation of exercise safety alarms when the exercise intensity or patient symptom scores exceed provider recommended maximum values [7]. The home telerehabilitation unit generates a detailed exercise log which is communicated to the patient rehabilitation team. This allows the patient providers determine which exercise settings are more challenging to the patient. There are also general exercise safety tips as well as specific tips for each exercise designed to minimize the risk of injury during exercise. A touch screen dashboard is used for the patient interface to start, stop or skip exercises according to the patient preferences and to receive feedback on the exercise status during patient exercise. The dashboard has been optimized for individuals with possible limitations in vision, locomotion, and cognition as shown in Figure 2. The patient unit includes a resistance chair (CFC-100B-S, VQ ActionCare, LLC, USA) that sends real-time exercise progress measurement data to the home rehabilitation unit.

1.2. Sensor platform and setup

The SpO2 module used a clip type plethysmograph sensor that was placed on one of subject's earlobes. Heart rate (HR) and SpO2 levels were updated every second. The exercise performance was monitored by paired magnetic switch sensors located on four resistance cable passing lines including upper-left, upper-right, lower-left and lower-right lines. The paired magnetic switch sensors were positioned between the starting point and the full extension point. In this study, sensor information, number of repetitions, exercise time and percentage of exercise similarity were calculated by detecting TTL signal with 50 Hz sampling rate. The exercise similarity was used to assess smoothness and synchronicity of limb movement and was calculated as percentage difference between movement of left and right cable lines during exercise.

2. Evaluation

The validity of the system was assessed by acquiring all physical sensor and physiological information in a simple prescribed exercise. The biceps-curl was used to represent lower cable exercises and the chest-press was chosen to represent upper cable exercises during testing. The testing included one set for each exercise consisting of 10 repetitions in this project. During the exercise session, the performance time was analyzed, and HR and SpO2 levels were calculated for each exercise set and the total exercise program. To analyze subject's exercise pattern, the percentage similarity was calculated and displayed for forwarding and returning patterns of exercise. The mean percentage of exercise similarity was calculated for each exercise set. To check the functionality of the system, tests were conducted to quantify the accuracy of exercise performance count. The accuracy of count was assessed by comparing the count generated by a blinded observer and the automated count indicator in the strengthening exercise program. During the test, the blinded observer was not able to see automatically generated counts of the subject's exercise performance. All counts obtained by the observer were identical to the counts identified by the computerized

Table 1. Descriptive statistics for all subjects

Subject	Duration (sec)			HR (beats/min)						SpO2 (%)					
	Bicep	Chest	Total	Bicep		Chest		Total		Bicep		Chest		Total	
				Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	77.1	71.3	182.2	88.3	2.0	87.0	1.3	87.7	1.8	100.0	0.0	100.0	0.0	100.0	0.0
2	66.1	66.9	145.9	95.9	1.3	98.2	0.6	97.1	1.5	99.9	0.3	99.7	0.5	99.8	0.4
3	69.7	64.4	151.1	106.5	4.0	107.0	6.2	106.4	5.2	100.0	0.2	100.0	0.0	100.0	0.2
4	68.0	65.0	146.4	69.5	5.1	63.9	0.4	66.4	4.5	100.0	0.1	100.0	0.0	100.0	0.1
5	76.1	71.9	164.6	65.8	2.3	69.8	0.4	67.9	2.6	100.0	0.0	100.0	0.0	100.0	0.0

Subject	Mean Similarity (%)					Count (times)						Accuracy (%)		
	Bicep		Chest		Total	Bicep		Chest		Total		Bicep	Chest	Total
	Pull	Release	Pull	Release		P	M	P	M	P	M			
1	65.1	95.1	89.8	83.6	83.4	10	10	10	10	20	20	100	100	100
2	61.9	87.9	44.5	76.0	67.6	10	10	10	10	20	20	100	100	100
3	85.8	82.2	80.5	94.2	85.7	10	10	10	10	20	20	100	100	100
4	92.1	76.3	85.6	86.1	85.0	10	10	10	10	20	20	100	100	100
5	90.7	90.5	61.8	91.1	83.5	10	10	10	10	20	20	100	100	100

HR=heart rate, SpO2=blood oxygen saturation level, Bicep=biceps curl, Chest=chest press, SD=standard deviation, Mean Similarity=mean percentage of similarity between left and right extremities, Bicep Pull=elbows forward (to fully shorten the biceps), Bicep Release=elbows back (to avoid over-active insufficiency and keep parallel forearms), Chest Pull=elbow extension (to press the handles forward), Chest Release=elbows back (to return the start position and keep the tension), P=numeric count from the program indicator, M= monitor's blind-count, and Accuracy=percentages of the accuracy of exercise count

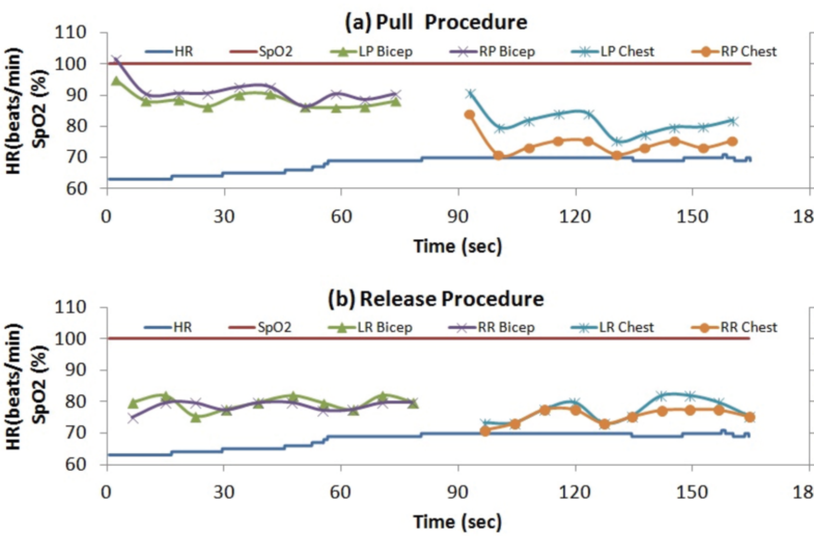

Figure 3. An example of all data from prescribed exercise procedure in subject 5.

HR(heart rate) and SpO2(blood oxygen saturation level) are indicated by the primary axis, other parameters are indicated by the secondary axis, LP Bicep=time difference between the first and the second sensing during the left elbow forwarding in the biceps curl exercise, RP Bicep=time difference between the first and the second sensing during the right elbow forwarding in the biceps curl exercise, LP Chest=time difference between the first and the second sensing during the left elbow extension in the chest press exercise, RP Chest=time difference between the first and the second sensing during the right elbow extension in the chest press exercise, LR Bicep=time difference between the first and the second sensing during the left elbow returning in the biceps curl exercise, RP Bicep=time difference between the first and the second sensing during the right elbow returning in the biceps curl exercise, LP Chest=time difference between the first and the second sensing during the left elbow returning in the chest press exercise, RP Chest=time difference between the first and the second sensing during the right elbow returning in the chest press exercise system. Overall five healthy volunteers participated in the testing. Table 1 shows a summary of subjects' acquired physical and physiological information during the exercise session, and Figure 3 presents data graphs from the prescribed exercise procedure. The descriptive statics in Table 1 illustrates the intra- and inter-subject variability in exercise performance indicators for the study exercises.

3. Discussion

A successful design of home-based platform for strengthening exercise in older adults has been implemented and its validity has been tested. The advantage of the proposed design is use of a simple affordable chair with linked elastic cables. This solution does not require bulky exercise equipment, significant additional space, excessive cost and specialized training. Exercising in a chair may be also much safer solution for many older adults with mobility impairments. People on wheelchair can also use such a system. Addition of exercise safety and quality is very important in the population of community dwelling older adults. Ability of the system to monitor cardiovascular parameters extends its potential use to people with cardiovascular conditions and frail elderly whose exercise otherwise has to be supervised in a specialized facility. The system design provides for clinical supervision allowing a rehabilitation team dynamically manage individualized exercise regimens and setting up individualized alert thresholds. Real-time performance monitoring and feedback supports quality of exercise program. Validity of the exercise monitoring has been confirmed by the results of this study. An interactive resistance chair has significant potential in facilitating home-based telerehabiliation by providing personalized exercise monitoring and performance feedback, communicating results to a care management team, and supporting safe and efficient exercise at senior patient homes.

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