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Perceptions of seniors with heart failure regarding autonomous zero-effort monitoring of physiological parameters in the smart-home environment

Sherry L. Grace, PhD [a,b,*], Golnoush Taherzadeh, MSc [b], Isaac Sung Jae Chang, BASc [c], Jennifer Boger, PhD [d], Amaya Arcelus, PhD [d], Susanna Mak, MD [e], Caroline Chessex, MD [f], Alex Mihailidis, PhD [c]

[a] York University, School of Kinesiology and Health Science, Bethune 368, 4700 Keele Street, Toronto, ON, M3J IP3, Canada
[b] University Health Network, Toronto Rehabilitation Institute, Cardiorespiratory Fitness Team; 347 Rumsey Road, Toronto, ON, M4G IR7, Canada
[c] Institute of Biomaterials and Biomedical Engineering, University of Toronto, Rosebrugh Building, Room 407, 164 College St, Toronto, ON, M5S 3G9, Canada
[d] Toronto Rehabilitation Institute, 550 University Ave., 12th Floor, Toronto, ON, M5G 2A2, Canada
[e] Department of Medicine, Division of Cardiology, Mount Sinai Hospital, 600 University Ave, Murray Side, Rm 18-365, Toronto ON, M5G 1X5, Canada
[f] University Health Network, Cardiac Rehabilitation, Toronto Western Hospital, 399 Bathurst St. West Wing, 5th Floor, Room 469, Toronto, ON, M5T 2S8, Canada

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ABSTRACT

Background: Technological advances are leading to the ability to autonomously monitor patient's health status in their own homes, to enable aging-in-place.
Objectives: To understand the perceptions of seniors with heart failure (HF) regarding smart-home systems to monitor their physiological parameters.
Methods: In this qualitative study, HF outpatients were invited to a smart-home lab, where they completed a sequence of activities, during which the capacity of 5 autonomous sensing modalities was compared to gold standard measures. Afterwards, a semi-structured interview was undertaken. These were transcribed and analyzed using an interpretive-descriptive approach.
Results: Five themes emerged from the 26 interviews: (1) perceptions of technology, (2) perceived benefits of autonomous health monitoring, (3) disadvantages of autonomous monitoring, (4) lack of perceived need for continuous health monitoring, and (5) preferences for autonomous monitoring.
Conclusions: Patient perception towards autonomous monitoring devices was positive, lending credence to zero-effort technology as a viable and promising approach.

Introduction

Heart failure (HF) is a complex cardiovascular disease requiring monitoring and management to optimize outcomes. Its burden is of epidemic proportions, affecting an estimated 26 million people worldwide in 2014.[1] HF is the leading cause of hospitalizations in Europe, the United States (over 1 million hospitalizations in both regions)[1] and Canada (305,000 Canadians hospitalized).[2] This is a significant burden to any economy.

HF is marked by symptoms such as breathlessness, orthopnoea, reduced exercise tolerance, fatigue and fluid retention. As such, heart rate, respiratory rate, blood pressure, and body weight, among others, are essential physiological parameters in monitoring the condition of HF patients, and whether they are self-managing appropriately in the community. Knowledge of these key parameters allows for provision of appropriate care and intervention, which may avoid acute decompensation, and hence expensive hospitalization.[3]

Indeed, HF self-management can mitigate the high-risk of mortality in this patient group. For example, HF patients are directed to weigh themselves daily, to ascertain whether they are retaining fluid and hence may be decompensating. If their weight

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* Corresponding author. School of Kinesiology and Health Science, Bethune 368, York University, 4700 Keele Street, Toronto, ON, M3J IP3, Canada. Fax: +1 416 736 5774
E-mail address: sgrace@yorku.ca (S.L. Grace).

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has increased, they can change their behaviours and seek care as appropriate, to mitigate decompensation and hence re-hospitalization. However, many patients may not follow advice to weigh themselves daily and hence autonomous assessment of weight could be very useful.

Some previous research has demonstrated that in-home health monitoring works in HF patients, and may even result in greater risk factor control,[4–6] improve quality of life, improve the quality of patient-provider relationships, shorten lengths of hospital stay, reduce mortality, all at much lower cost.[7–11] However, many seniors are unfamiliar with the methods, frequency or actions required to self-monitor their HF, or are unable to operate the devices required to do so. Indeed a recent review concluded technological acceptance and perceptions of usability in older adults, including those with cardiovascular diseases, are low.[12] Progress has been made in the development of "zero-effort technology" which autonomously monitors physiological parameters without any conscious effort from users.[13] The availability of this technology could facilitate accurate and continuous ambient monitoring of important physiological parameters for HF patients, without any patient burden, patient-related error or failure.

However, for such a system to be implemented, it must be acceptable to the user. Thus, the objective of this study was to understand the perceptions of seniors with HF regarding a smart-home system to autonomously monitor their physiological parameters, namely heart rate, blood pressure, temperature, weight, and respiration.

Methods

Design

This was a qualitative sub-study of a larger cross-sectional observational study designed to design and pilot test a smart-home system. The design of the technology and the development of the interview guide were informed by the Human Activity Assistive Technology (HAAT) theoretical framework.[14] This is a model to guide assessment, prescription and evaluation of assistive technology solutions, which focuses on persons with disabilities, their activities and social context. Ethics approval was obtained from participating hospitals.

Procedure

Participants were recruited from one of 4 ambulatory clinics: 2 heart function clinics and 2 cardiac rehabilitation programs at 4 academic hospitals downtown Toronto, Canada. Where patients provided written informed consent, clinical data was extracted from participants' medical charts. If they met inclusion/exclusion criteria, a testing session was scheduled for participants in the lab.

On the day of the test, participants were first oriented to the test procedures and asked to complete some questionnaires. Then participants performed a predefined set of activities of daily living throughout the smart-home as shown in Table 1. They involved regular daily activities such as watching television on the couch, walking, performing light housework duties, reading at the dining room table, and lying in bed. The system was simultaneously tested against gold standard measures of the physiological parameters being assessed (i.e., wearable heart and respiratory rate monitors, blood pressure cuffs, a weight scale, a clinical thermometer and motion trackers). Results regarding the accuracy of these technologies in comparison to gold standard measures will be reported elsewhere.

Each testing session was concluded with the semi-structured interview, which is the focus of this paper. The interviews were led by a registered nurse or nurse-trainee. Participants were asked for verbal consent to digitally record the interviews. The interviews were recorded and later transcribed verbatim, except to preserve anonymity.

Setting

The smart-home system was designed, set up and pilot-tested on healthy adults in the HomeLab at the University Health Network- Toronto Rehabilitation Institute, in Ontario Canada. The HomeLab resembles a typical single-storey dwelling with a bedroom, bathroom, kitchen, dining room and living room, as shown in Fig. 1. There was also a set of stairs to a small second floor landing area. The lab has functional electrical wiring and plumbing.

The smart-home was crafted by embedding passive sensors into the HomeLab and commonly-found objects and furniture. The research team used commercially-available sensors, and added novel post-processing software to obtain the highest signal strength and most reliable measurements from the smart-home context. The following 5 sensing modalities were tested: (1) A network of 16 accelerometers installed on a blanket (used in the bedroom) to capture chest motion and calculate respiration; (2) Capacitively-coupled (CC) electrodes and load cells installed on a chair (used in the dining area) to record electrocardiogram (ECG) and ballistocardiogram (BCG), which can be used to measure heart rate and blood pressure; (3) Load cells employed under the legs of the bed to measure body weight; (4) Infrared thermometry for non-contact body temperature recording from a person's face while he

Table 1
Activity sequence.

	Activity	Test device (Embedded in)	Physiological Parameter
1.	Pt asked to get in bed; Covered with blanket fully and asked to lie for 5 min	Accelerometers (blanket) and force sensors (bed)	Respiration and weight
2.	Walked to washroom; While sitting down on a chair, place feet on floor tile for 1 min	Electrodes (Floor tile)	HR
3.	Stand still on floor tile for 1 min	Force sensors and electrodes (Floor tile)	HR, SBP, and weight
4.	Stand - Cold Pressor Test: - Insert one hand in cold water, leave for 1 min - Remove hand, compare BP and HR to baseline to ensure values are in normal ranges - Dry hand;	Force sensors and electrodes (Floor tile)	HR, SBP
5.	Simulate hand washing while standing for 1 min	Force sensors (Floor tile)	HR
6.	Walk to dining table; Sit at dining table, lean back on the chair; Drink tea, read newspaper for 5 min	CC-electrodes and force sensors (Chair)	HR, weight, and SBP
7.	Walk to couch; Sit on couch, watch TV for 5 min; Record body temperature using a thermometer	CC-electrodes (Couch) Thermal camera (beside television)	Body temperature and HR
8.	Walk to stairs; stair exercise: - Climb up and down stairs until HR is 20–30 bpm higher or until evidence of shortness of breath, up to 2 min	CC-electrodes and force sensors (Chair)	HR, weight, and SBP

HR = Heart Rate; SBP = Systolic Blood Pressure; CC = Capacitively-coupled.