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Review article

Smart homes and home health monitoring technologies for older adults: A systematic review

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ABSTRACT

Background: Around the world, populations are aging and there is a growing concern about ways that older adults can maintain their health and well-being while living in their homes.
Objectives: The aim of this paper was to conduct a systematic literature review to determine: (1) the levels of technology readiness among older adults and, (2) evidence for smart homes and home-based health-monitoring technologies that support aging in place for older adults who have complex needs.
Results: We identified and analyzed 48 of 1863 relevant papers. Our analyses found that: (1) technology-readiness level for smart homes and home health monitoring technologies is low; (2) the highest level of evidence is 1b (i.e., one randomized controlled trial with a PEDro score ≥6); smart homes and home health monitoring technologies are used to monitor activities of daily living, cognitive decline and mental health, and heart conditions in older adults with complex needs; (3) there is no evidence that smart homes and home health monitoring technologies help address disability prediction and health-related quality of life, or fall prevention; and (4) there is conflicting evidence that smart homes and home health monitoring technologies help address chronic obstructive pulmonary disease.
Conclusions: The level of technology readiness for smart homes and home health monitoring technologies is still low. The highest level of evidence found was in a study that supported home health technologies for use in monitoring activities of daily living, cognitive decline, mental health, and heart conditions in older adults with complex needs.

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1. Introduction

In many countries of the world, populations are aging at an increasing rate, as fertility rates decline and life expectancy rises [1]. As a result, the population ratio of older adults relative to the total population is increasing. According to a report released by the United Nations, the proportion of persons aged 60 years and older, compared to the total population, is expected to double between 2007 and 2050, and reach 2 billion by 2050 [2].

Placement in a care facility, especially when it occurs against an individual's wishes, has been associated with negative effects such as depression, social isolation, and greater dependency in completion of self-care tasks [3]. Therefore, older adults prefer to stay in their homes rather than enter a healthcare institution when they need specialized care. For example, in a survey undertaken in the United States, 30% of those over 65 years stated they would "rather die" than enter a nursing home [3]. Burden and costs of care not only rise in the healthcare system but also for informal caregivers (i.e., family members, friends, neighbours). The significant costs associated with the provision of care to an aging demographic, as well as shortages in the health workforce, have spurred both industry (e.g., Elite Care, Intel, Tunstall) and academia to undertake research on the efficacy and feasibility of health monitoring and assistance provided in the home environment [4].

To the best of our knowledge, no literature review about smart homes and home health-monitoring technologies have characterized the quality (as scientific evidence over health outcomes) of the studies carried out with these technologies or the level of technology readiness. The aim is to provide a comprehensive review that characterizes the state of the art of smart homes and home health monitoring technologies. The specific research questions of this review are:

1. What is the clinical evidence of the outcomes in studies on smart homes and home health-monitoring technologies for older adults with complex needs?
2. What is the level of technology readiness for smart homes and home health-monitoring technologies intended for older adults with complex needs?

This paper has six sections including the Introduction (Section 1). We present a general background about the concept of technologies for older adults in Section 2. Then we describe the data sources and method used to locate and select the relevant literature in Section 3. Next, we present the results, where the research questions are answered in Section 4. In Section 5, we identify the main research gaps and make suggestions for future research. Section 6 is our conclusion.

2. Theoretical background: gerontechnology, smart homes and home-based consumer health technologies for older adults

In the United States, the prevalence of multiple chronic conditions in older adults exceeds 60%. According to the American Geriatrics Society, complex needs are chronic conditions that frequently require services from different health care practitioners in multiple settings including frequent hospitalizations [5]. Older adults with complex needs are limited in their ability to perform basic daily activities due to physical, mental and psychosocial challenges requiring complex continuing care [5]. Technology tools provide the possibility for older adults with chronic conditions and complex needs to remain at home and maintain an acceptable quality of life [6,7]. Technological innovation for older adults is occurring at an unprecedented rate [8]. "Gerontechnology" is a term that combines gerontology and technology, coined to describe an interdisciplinary field of science for "designing technology and environment for independent living and social participation of older persons in good health, comfort and safety" [9]. The term "smart home" refers to a special kind of home or residence equipped with sensors and actuators, integrated into the infrastructure of the residence, intended to monitor the context of the inhabitant to improve his or her experience at home [10,6]. Smart homes can enable older adults to live independently at home longer and reduce their reliance on informal or formal caregivers, or allow caregivers to better care for older adults. These technologies have the potential to provide a cost-efficient approach to enhance one's quality of life and help older adults live safely in their homes [11]. A smart home can potentially provide a variety of services spanning from simple task automation (e.g., room-temperature control), to analysis or prediction of the location of a resident, to behaviour or health status recognition of an occupant living at home, with subsequent transmission of collected data for remote monitoring. In health care, there are two key applications for smart homes: "(a) home automation: remote or automatic control of devices, appliances, or systems at home to enhance an occupant's quality of life, or to manage energy consumption; and (b) monitoring wellness: monitoring an occupant's health-status to maintain his or her well-being" [11,p. 4].

Technologies can be used to monitor wellness of older adults with complex needs living at home. These are not necessarily embedded in the residence or building structure, but are designed for home use by older adults with complex needs and their families, and include wearable sensors to detect changes in vital signs [12]. Examples of home health-monitoring technologies are systems for physiological monitoring (*Phys*), functional monitoring and emergency detection and response (*Fx*), safety monitoring and assistance (*Saf*), security monitoring and assistance *(Sec)*, social interaction