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EVALUATION OF WEARABLE HEALTH TECHNOLOGIES IN ALZHEIMER'S PATIENTS: A SYSTEMATIC REVIEW*

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Research Article

Abstract

Aim: This study aims to identify the use areas of wearable health technologies developed for Alzheimer's patients and to present the results obtained.

Methods: The study was conducted using the systematic review method. Scanning was carried out on Medline, Scopus, and Web of Science (Core Collection) electronic databases.

Results: The scanning resulted in 798 publications. At the end of the detailed full-text analysis, 5 articles that were found to be suitable for the study were evaluated. Usage areas of WHTs have been determined

to prevent possible falls, plan daily activities (personalized care planning, medication follow-up, disease management), and improve recall and autobiographical memory.

Conclusion: The research is important in terms of giving information about wearable health technologies that developed for Alzheimer's patients. However, we need more evidence related to the use of these technologies. The study additionally observed that the social media effect significantly affects the impulse purchases of consumers.

Keywords: Alzheimer's Disease, Wearable Health Technology, Wearable Devices, Biosensor, Systematic Review

INTRODUCTION

The elderly population is increasing rapidly throughout the world, including in developed and developing countries (WHO, 2011; WHO, 2021). In parallel with the increase in the elderly population, the frequency of chronic diseases is also increasing (Bilir, 2006). Alzheimer's Disease (AD), a chronic brain disorder like all neurodegenerative diseases, is the most common type of dementia (Acosta and Wortmann, 2009; OECD, 2013) and is among the most common chronic diseases in the elderly population (Bilir, 2006). Due to the aging of the population and the increase in the number of elderly individuals with AD (Eroymak and Yiğit, 2017; Eroymak and Yiğit, 2020; OECD, 2013), the use of technological solutions developed to help these patients gain importance (Maresova et al., 2018). In this context, it is seen that there is an increased interest in health technologies that address the health problems of the elderly population and can contribute positively to their lives. These technologies make a significant contribution to meeting the needs of elderly individuals in all areas related to basic health services, personal care, safety, protection, independence, and participation in social life (Ekici and Gümüş, 2016).

The health care needs of the elderly are an important and priority issue. AD, negatively affects the cognitive and physical capacities of patients, causing them to need long-term care (Aşiret and Kapucu, 2015; OECD, 2013). The need for long-term care increases the importance of technical support in care processes. For this reason, the development and use of wearable health technologies are increasing rapidly for Alzheimer's patients to maintain their independence, improve their cognitive status, mood, and social functions, and reduce unnecessary service use (Maresova et al., 2018).

Wearable health technologies; it is defined as electronic and computer-based devices such as jewelry, watches, glasses, clothes, hair bands, wristbands, implants that can be carried

on the body to collect data on the health status of individuals (Özkan, Yeşilaydın and Bülüç, 2018; Wright and Keith, 2014). Thanks to wearable health technologies, it is possible to motivate individuals to monitor and evaluate their health status and to control their health (Aydan and Aydan, 2016). As a matter of fact, with these health technologies, all kinds of data that inform the health status of users such as sleep patterns, heart rate, the number of calories burned, body temperature, sugar, and oxygen levels in the blood can be collected. The data obtained can be used to monitor the health status of individuals and to carry out the diagnosis and treatment process. Thanks to wearable technologies, it has become possible to monitor individuals with chronic health problems 24 hours a day, 7 days a week (Özkan, Yeşilaydın and Bülüç, 2018). In addition, thanks to remote monitoring and monitoring systems, patients' health information during the day (heart rhythm level, etc.) can be obtained with the help of sensors, and they can create warnings or alarms when necessary (Ekici and Gümüş, 2016). This provides the opportunity for early intervention in case of any negativity (Sopic et al., 2018). Similarly, wearable technologies are also used for security purposes. For example, with accelerometer-based wearable sensors, it is possible to detect and prevent negative and abnormal situations that patients may experience such as falling, exposure to high heat or smoke (Ekici and Gümüş, 2016). In short, thanks to wearable health technologies, it is possible to continuously monitor the health results of individuals and to intervene remotely and instantly (Ouertani et al., 2017; Şimşir and Mete, 2021). This situation reduces the time individuals spend in health centers and contributes to a better quality of life in their environment. In recent years, smart home systems have been developing to include remote monitoring. Thanks to these developments, it becomes possible to obtain data that can be used in the long term by making use of the activities of the patient in the environment and the wearable sensor data on it (Ekici and Gümüş, 2016). In addition, the integration of these technologies into health services removes time and location restrictions and creates a more flexible health system (Şimşir and Mete, 2021). As a matter of fact, with the integration of wearable health technologies into health services, service providers have more information about the users of the service. This situation plays an important role in the development of personalized, informative, preventive, protective, and interventional health services for individuals. Wearable health technologies also have a positive effect on improving the quality of life of individuals (Aydan and Aydan, 2016). However, some problems may be encountered in integrating wearable health technologies into the health system and the lives of users (Habibipour, Padyab, and Ståhlbröst, 2019; Padyab and Habibipour, 2021). In addition, there are some obstacles in the implementation of these technologies, as they are relatively expensive and cause privacy and security concerns about patient data (Wright and Keith, 2014).

However, it is stated that the widespread use of these technologies is extremely beneficial in terms of reducing the delivery costs of health services, providing quality and effective services, facilitating access to services, and providing remote control of the health status of users (Özkan, Yeşilaydın and Bülüç, 2018).

It is stated that the interest in the development of wearable health technologies has increased in recent years, especially to help Alzheimer's patients who need to be constantly monitored and kept under control (Maresova et al., 2018; Ouertani et al., 2017). It is seen that these technologies have been developed and used intensively to locate Alzheimer's patients, monitor them remotely, ensure their safety, plan daily life activities such as nutrition, taking medication, exercising, and meeting their socialization needs (Abbate, Avvenuti and Light, 2012, Abbate, Avvenuti and Light, 2014; Buckley et al., 2019; Grierson, Zelek and Carnahan, 2009; Khattak et al., 2011; Ouertani et al., 2017; Woodberry et al., 2015). It is stated that the data obtained within the scope of wearable health technologies have an important place in diagnosing Alzheimer's patients, monitoring the patients, and developing their treatments (McCarthy and Schueler, 2019).

In this systematic review, as it was aimed to identify and compile the results of wearable health technologies developed for Alzheimer's patients and also experimentally tested on Alzheimer's patients. In other words, it is to determine in which areas wearable health technologies are used for Alzheimer's patients and to compile experimental studies and results for these areas. In addition to these, in particular, we aimed to clarify the following aspects too: (a) Which technologies have been used? (b) How did patients react to these technologies? (c) What is the purpose of the WHT used? (d) What is the clinical significance of WHT? (e) What is the benefit of WHT to patients or their families?

1. RESEARCH METHODOLOGY

First of all, we determined the search strategy by getting support from a database expert. We set our inclusion and exclusion criteria. Then, we developed a common search strategy for all databases in line with the possibilities offered by the databases. Table 1 shows examples of this strategy. Studies were obtained by searching electronic databases and pooling in Mendeley, the online reference management software. MEDLINE, SCOPUS, and WEB OF SCIENCE (CORE COLLECTION) were used as an electronic database. The scan was conducted between 1-31 June 2020. Since the topic is up-to-date, the date restriction was not used while searching. An

ethical committee report was not necessary for this study which used secondary data derived from the literature.

Table 1. The Search Words Used in Databases

Databases	**Search words**	**Number of articles**
Medline	(MH "Alzheimer Disease") OR (TI alzheimer) AND wearable technology OR wearable devices OR wearable sensor OR biosensor OR wearable	153
Web of Science (Core Collection)	TS=(alzheimer disease OR alzheimer) AND TS=(wearabletechnology OR wearable devices OR wearable sensor OR biosensor OR wearable)	319
Scopus	(TITLE-ABS-KEY ("Alzheimer disease" OR "alzheimer")) AND (TITLE-ABS-KEY ("wearable technology" OR "wearable devices" OR " wearablesensor" OR biosensor OR wearable)) AND (LIMITTO (LAN GUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "ar")	326

The two authors decided on inclusion and exclusion criteria, and in case of disagreement, a consensus was reached through verbal deliberation. Articles were selected according to inclusion and exclusion criteria. Because the main purpose of this study is to determine the testing areas of wearable health technologies on Alzheimer's patients. The studies were examined using content analysis to discuss the results of the studies, the methods used, the purpose of the study in detail, and to obtain answers to the research questions.

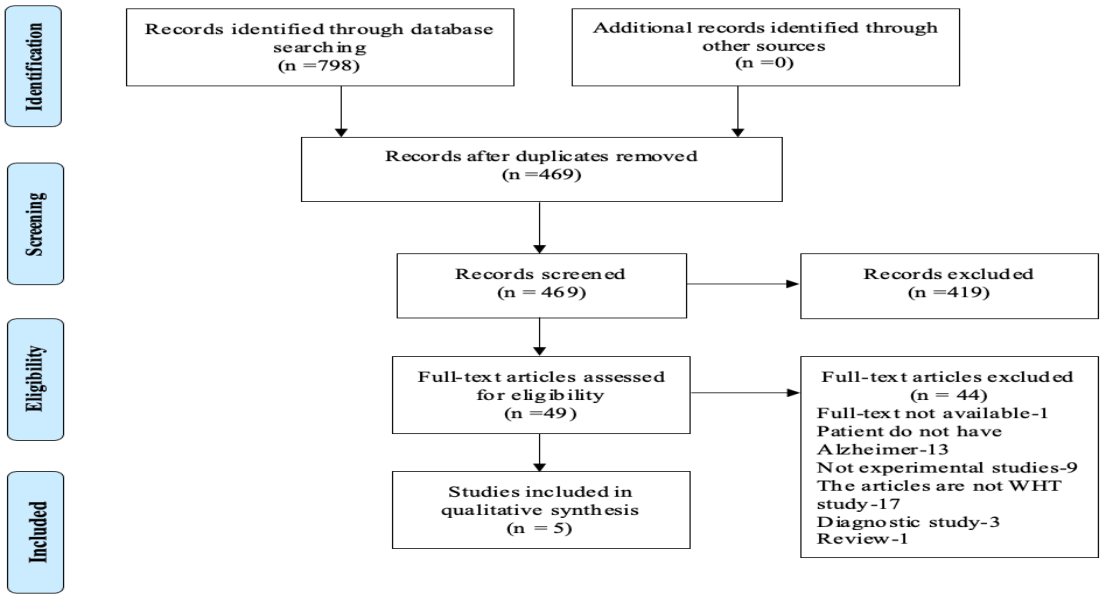

Figure 1: Prisma Flow Chart

After searching the databases as given in Table 1, a total of 798 articles were reached. By examining the titles and abstracts of these articles, the articles found suitable for the study were tried to be selected. Although the title and abstract section were examined, full-text analysis was made in the unsure articles. After this stage, 49 articles were included in the full-text review. A full-text review was conducted for 49 articles, taking into account the inclusion and exclusion criteria. As a result, 5 articles that met the inclusion and exclusion criteria were reached.

Inclusion Criteria

The included studies consisted of articles published in English with full texts available. It was essential in the studies that wearable health technologies were tested on Alzheimer's patients.

Exclusion Criteria

Non-article publications - papers, book chapters, editorials, commentary pieces, and opinion articles are excluded. Wearable health technology studies in patients with Parkinson's and other forms of dementia were not included.

2. FINDINGS

In the articles we included in the full-text examination; Studies have been conducted on usability and acceptability, planning of daily life, contribution to cognitive development, testing of a heterogeneous motion detection sensor (Abbate, Avvenuti and Light 2014; Buckley et al., 2019, Silva et al., 2017; Woodberry et al., 2015; Khattak et al., 2011).

Table 2. Summary of Studies

Study ID	Subjects	Purpose	Method	Results	Conclusion	Usage Areas
Abbate et al., 2014	4 patients with AD (age 75-92)	Testing WHT's usability and acceptability	Patients staying that long-term nursing home were observed for 1 month. Patients have worn shimmer sensor and Enobio sensor for 1 month.	It has been concluded that ergonomics and aesthetics are important for patients to accept these devices.	The design and development of a monitoring device must consider its target users' preferences.	Prevent possible falls
Buckley et al., 2019	36 patients with AD (age 71-83) and 26 person control	In-depth analysis of walking behavior	Participants were asked to wear a tri-axial accelerometer continuously on the lower back for one week. Upon completion of the recording, participants removed the device and sent it back.	Gait variable time-series of walking activity were significantly different between groups for one hour during the evening hours (between 18:00 and 20:00)	The application of SPM may therefore help indicate when impairments occur and may contribute toward personalized care, disease management, and targeted intervention strategies for people with AD.	Gait analysis, disease management, personalized care, medication follow-up
Silva et al., 2017	46 patients with AD (age 62-80)	The cognitive effects of wearable cameras	Patients were divided into 3 groups (Memo, SenseCam, Diary). The data were collected for 6 weeks, and the researcher and the subjects were interviewed 11 times.	SenseCam provides a clear and continuous benefit for the recall of autobiographical memories.	As a result of the study, improvements were found in autobiographical memory, which was greater than other forms of memory rehabilitation and continued six months later.	Autobiographical memory rehabilitation
Woodberry et al., 2015	6 patients with AD (age 64-84)	Providing evidence that SenseCam improves the ability to remember	The experimental period lasted 3.5 months. The study followed a within-subject longitudinal design, comparing the effects of using Sense-Cam vs. a written diary to aid retrospective recall of significant personal events. The patients were given a SenseCam and a laptop computer, with detailed instructions on how to use both. The process was followed by the wife of the patients and the experimenters.	The subjects were able to remember the events they did not remember while looking at the SenseCam images.	Whether the improvements in the recall will occur in the long term is not yet known, but positive results have been obtained in the short term.	Make it easy to remember
Khattak et al., 2011	A patient with AD (age not specified)	Focusing on activity recognition using video-based, wearable sensor-based, and location-based activity recognition engines	The heterogeneous sensor system was placed in a test center for a patient with AD, and observations were made.	It has been observed that the human activity recognition engine (HARE) works well for patients with AD.	The HARE system can also be used for diseases such as Parkinson's and depression.	Remote monitoring of the individual with the control of daily activities and reminders

In the articles, we identified the use of a fall tracking sensor, a wearable camera to facilitate recall, a wearable device that collects gait analysis data, motion detection placed in the living environment, and a heterogeneous sensor system that allows remote control and monitoring (Table 2). In this case usage areas of WHTs; It has been determined as preventing possible falls, planning daily activities (personalized care planning, medication follow-up, disease management), improving recall and autobiographical memory. The fact that wearable health technologies have been studied in a small number of Alzheimer's patients is among the important results we have obtained, and it is among the points emphasized in the articles we included in the research (Abbate et al., 2014, Silva et al., 2017). Another important issue in the use of WHT's by Alzheimer's patients is that their usability and acceptability by patients are also important, as well as facilitating the care of patients and improving their health status (Abbate et al., 2014).

Wearable health technologies have the goal of being curative as well as making the lives of patients and their relatives easier. The results of SenseCam (Table 2), especially used to improve memory, are quite exciting (Silva et al., 2017; Woodberry et al., 2015). However, much more randomized controlled experimental studies are needed in this area. The use of the wearable camera with clinically positive results is possible with the help of patient relatives or care nurses. It is thought that a person living alone and at the beginning of his illness may need to be reminded of the use of the device by a staff member. The heterogeneous sensor system, on the other hand, can provide a great convenience for patient relatives in terms of facilitating the work of nursing nurses in nursing homes. Thanks to the device that performs the gait analysis of the person, the time intervals where the patient's follow-up should be done more tightly, the planning of the person's day (such as the time to take a walk) will make the patient's care process more quality and comfortable.

The inclusion of 5 articles (Table 2) as a result of the screening reveals that the studies on the subject are insufficient. On the other hand, besides the fact that not all studies are randomized controlled studies, the studies were not deemed sufficient in terms of duration and number of patients, too. In studies, it has been determined that Alzheimer's patients have different levels of diseases such as advanced, mild, and moderate (Abbate et al., 2014; Silva et al., 2017; Woodberry et al., 2015). In fact, this point appears to us as a different criterion in the diversity of studies in the field. In other words, it is not enough for wearable health technologies to be studied only on

Alzheimer's patients. The results should be carefully evaluated by working with Alzheimer's patients at different stages of the disease. In other studies, we see that wearable technologies are also used and studied to detect subtypes of dementia and to diagnose Alzheimer's disease early. In particular, wearable gait analyzers are promising for the future with the development of algorithms that can analyze these data (Hsu et al., 2014; Avitabile, Coviello and Margiotta, 2015). This actually guides us that wearable health technologies can be useful not only after diagnosis but also in early diagnosis.

3. DISCUSSION

The rapid change in health technologies, the increase in chronic diseases, the aging of the population, the increase in the expectations of patients and their relatives, the demand for access to health information, the increase in the health literacy level of individuals have brought the issue of wearable health technologies in health services to the agenda (Özkan, Yeşilaydın and Bülüç, 2018; Wright and Keith, 2014). There has been an unprecedented increase in the development of these technologies in the healthcare field (Maresova et. al., 2018), and a variety of products continue to be developed. Among these products, wearable medical sensors, motion sensors, bed sensors, medication reminders, and dispenser systems developed for remote monitoring are used extensively (Ekici and Gümüş, 2016). The increase in users' interest in wearable health technologies also reveals the importance of these technologies in the health sector. As a matter of fact, these technologies provide effective solutions to the problems of disabled individuals, patients with chronic health problems and the elderly, and play an important role in facilitating their daily lives (Özkan, Yeşilaydın and Bülüç, 2018).

Increasing health problems of elderly individuals generally increase the economic and psychological burden on society and individually on their families (Maresova et al., 2018). Especially in dementia-type diseases such as AD, which the elderly population suffers from, the needs of caregivers to cope with this disease arise (Matthews et al., 2015). In this respect, the development of health technologies that will contribute to the independent life of these patients gains importance (Powell-Cope, Nelson and Patterson, 2008). It is stated that the restriction of the lives of Alzheimer's patients, who need to be kept under constant surveillance, creates an important area of difficulty for them. In this context, a wearable device that allows these patients to interact

with their families and relatives in a secure and limited social network area has been developed and put into use (Ouertani et al., 2017). Similarly, it has been determined that another wearable device developed to help Alzheimer's patients who have significant deterioration in their periodic memories to remember events has a positive effect on the autobiographical memories of the patients (Woodberry et al., 2015). The results obtained from another wearable sensor, which was developed for the planning of daily living activities of Alzheimer's patients, revealed that this device is useful for providing better care to patients (Khattak et al., 2011). As can be seen, with the development of wearable health technologies, solutions have been found to various problems experienced by elderly individuals with AD. Developments in wearable health technologies have also increased the success in medical applications.

However, an issue as important as the development of technologies is the adoption of these technologies by older individuals who use them. While some technologies are adopted very quickly, the adoption and acceptance of the use of some technologies are at a lower level (Dunn, Runge and Snyder, 2018; Mitzner et al., 2019; Padyab and Habibipour, 2021). Another issue to be considered is ensuring that individuals do not give up on the use of technologies that they easily adapt and use at the beginning. For this reason, these technologies must be interesting and flexible enough to be used by individuals (Aydan and Aydan, 2016).

The negative mental state created by social isolation causes the health problems of elderly individuals to worsen and their quality of life to decrease (National Academies of Sciences, Engineering, and Medicine, 2020). Similarly, the restriction of the lives of Alzheimer's patients, who must be kept under constant surveillance, poses a significant challenge for their social life (Ouertani et al., 2017). As a matter of fact, it is stated that the use of health technologies based on social needs will contribute to the happiness of elderly individuals (Ekici and Gümüş, 2016) and will have a positive effect on improving their quality of life (Aydan and Aydan, 2016; Pulli et al., 2012). Considering the physical and mental health problems of the patients in question, it is thought that the comfortable use of the devices developed will increase the expected effect of WHTs on patients and the disease. However, more qualified studies are needed to clearly demonstrate this effect. In addition, the need to increase the number of participants in the studies is among the important results obtained.

The articles in this study; focused on usability and acceptability, planning of daily life, contribution to cognitive development, testing a heterogeneous motion detection sensor. These issues should be studied further and their effects on individuals such as patients, their relatives, and health personnel should be revealed. As the studies are carried out, the benefit of individuals from WHT will increase by identifying the deficiencies and making the regulations. In particular, the results of the article, which tests the usability and acceptability of wearable devices, draw attention to ergonomics and aesthetics, which are not in the foreground (Abbate et al., 2014). Even if it is an extraordinary device, a device that is not used by patients will not benefit anyone. Therefore, there is a need for wearable devices that care about the comfort of the patient and perhaps need to be personal specially designed.

Considering that the number of Alzheimer's patients will increase further shortly (Alzheimer Association, 2021), increasing more experimental, observational, and case-controlled studies of WHTs on Alzheimer's patients will be a proactive approach in terms of preparation for this disease. It is also important to evaluate the developed devices within the scope of health technology evaluation. The increase in the number of WHT soon will facilitate the development of the health policies of countries. Conducting cost studies will also facilitate decision-making processes on an institutional basis or in long-term care homes.

Developments in the field of wearable health technologies guide and support digital transformation in the fields of health education, health policies, and policy implementations. In this respect, it is foreseen that the full integration of these technologies into health systems will increase the benefits of the applications in health services, decrease the costs and minimize the errors in the process. Therefore, technology companies, policymakers, patient relatives, researchers, and even insurance companies need to work together (Maresova et al., 2018). This is important in terms of considering WHTs from different perspectives.

4. CONCLUSION

As a result of the evaluation, it was determined that WHTs were used to prevent possible falls, to plan daily activities (personal care planning, medication follow-up, disease management), to improve recall and autobiographical memory in individuals with AD. There are different wearable devices in the evaluated articles. More studies should be done to clearly state the benefits of these

wearable technologies on Alzheimer's patients and their relatives. The research is important in terms of providing information about wearable health technologies developed for Alzheimer's patients. However, need more evidence related to use of these technologies. In this context, it is recommended to make further research that has high evidence value such as meta-analysis about the use of wearable health technologies in these patients.

In this article, publications published outside of "Scopus, Web of Science, Medline" databases, which have a language other than English and whose full text is not available are not included. This situation constitutes the limitation of the study. In addition, in this study no quality assessment was made. However, if the number of WHT studies on Alzheimer's patients increases, it may be possible to conduct systematic studies with quality assessment. In this case, it is recommended to use quality assessment checklists and various quality assessment tools for systematic reviews and meta-analyses. This situation also was constituted the second limitation of the study.

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