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DIGITAL HEALTH: ANALYZING WEARABLE DEVICE IN ELDERLY CARE

A narrative literature review

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THESIS
Abstract

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Abstract

Abstract

The aging population is increasing, and so is the need for healthcare services for the elderly. The use of wearable devices is not familiar to many especially the aging population. Wearable devices allows the elderly to benefit from a variety of health monitoring and safety features for the elderly, allowing them to live more independently. This thesis seeks to determine what wearable devices are available to the elderly population, and whether these wearables are useful for people in this elderly population.

The research methodology employed for this thesis was the narrative literature review. The following electronic databases was used for relevant literature: PubMed, EBSCOhost / Cinahl Complete, ScienceDirect and Google Scholar and the data result was analysed using Thematic analysis. The literature examines twenty-five (n-25) articles for this study. This study will consider “the elderly” as adults over the age of 65, living in a service house or at home.

The results showed that most elderly are willing to adopt wearables devices as a tool for promoting personal health and the wearable device available for elderly are personal emergency response system, medication reminder device, hearing aids wearables and GPS tracking devices.

Wearable devices have the possibility to transforming healthcare for the elderly. They can provide a range of health monitoring and safety features, allowing elderly users to live more independently. However, future work should research the usability of wearables in developing countries must be addressed to ensure the widespread adoption of these devices.

Keywords
Digital health, wearable device, technology, elderly care

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Glossary: Abbreviations of terminology

AI	Artificial Intelligence
e-Health	Electronic Health
GPS	Global Positioning System
HER	Electronic Health Record
HIT	Health Information Technology
IoT	Internet of Things
LSTM	Long short-term Memory
MhNet	Multi-scale Spatio-temporal Hierarchical Network
NGO	Non-governmental Organization
PERS	Personal Emergency Response System
ML	Machine Learning
TAM	Technology Acceptance Model
WD	Wearable Device
WHO	World Health Organization
4P	Predictive Preventive Personalized Participatory

1 INTRODUCTION

The population of human on earth is aging rapidly; according to the World Health Organization, there will be 1 billion persons over the age of 60 in 2019 and that by the end of 2030, there will be 1,4 billion and 2,1 billion, respectively by 2050. These growing numbers of elderly need to be cared for. As people age, biologically the immune system functionality reduces which may result in sudden death or increase vulnerability to virus and diseases. (World Health Organization 2021)

The term “Aging” refers to the process of becoming older, which typically involves a decline in physical and nonphysical function of the body over time. The causes of ageing are complex and multifactorial and include both genetic and environmental factors. While aging is a natural process that affects all living organisms, there are certain lifestyle choices and interventions that can help to hold back or mitigate the effects of ageing (World Health Organization 2022).

Borgoni, Kudryashova, Burka & De Magalhäes 2021, define aging as a complex process that causes loss of homeostasis and increasing functional degradation in almost all human cells and organs. The authors describe the human immune system as among the most dysfunctional systems during aging, with changes in biochemical and physiological processes having a substantial impact on the organism's general health. The primary functions of the immune system are to protect the host from infections, maintain homeostasis by removing dead cells, and control the healing process (Borgoni, Kudryashova, Burka & De Magalhäes, 2021).

Many factors, however, influence how people age according to the WHO (2021). Lifestyle factors such as, environment, social status, educational background influence peoples’ health as they age. (World Health Organization 2021)

Physical and social environments contribute positively to the general public health and promote longevity in aging however, physical activities often decrease as people age, and this has been a leading health problem globally. (World Health Organization 2021)

Today’s healthcare services aim to deliver fast healthcare services, health monitoring, prevention and patient orientated care meaning people have more influence in making decisions or participate in the service they get. Wearable device usage has increased and simultaneously developed into the form of body inserts, body attachment, body wearable/clothes and integrated and accessories (Guk et al, 2019).

Wearables have a sensor that provides data for end users either numerically or by visually assessment. Numerical assessment involves using numbers and quantitative measurements to evaluate results, while visual assessment involves using visual cues and qualitative observations to evaluate results. This data potentially improves health results and outcomes. However, given how quickly they develop, assessing the effects of physical activity technology can be difficult. (McCallum, Rooksby, Gray 2017)

Generally, wearable technology has been widely employed in the healthcare industry for a variety of purposes, including patient care and personal health. A wearable device uses sensors or other

technologies for assessment of illness, care management, tracking, and treatment of long-term illnesses, and disorders. (Uddin, Syed-Abdul, 2022).

A wearable device application in healthcare has its own advantage in management or prediction of some medical condition. There are many wearable devices in today's market, however, the information available for usage of wearable devices in elderly populations is limited. This research seeks to understand the perception of the aging population on wearables, and what devices or technologies are available for elderly care, and what are the possible challenges with healthcare data and privacy that can be experienced when using these devices.

2 BACKGROUND

Digital Health

Digital health can be described as using technologies to provide and improve healthcare services in complement to the conventional mode of delivering healthcare services. The conventional mode of providing healthcare services require healthcare services seekers to be physically available with healthcare professionals either at the hospital or at the outpatient clinic. Digital health has the potential to transform the way healthcare is delivered, making it more accessible, affordable, and personalized. It can help people monitor their health, manage chronic conditions, and access healthcare services remotely, which can be especially beneficial in rural or underserved areas. Additionally, digital health solutions can improve the efficiency of healthcare systems, reduce costs, and improve patient outcomes. (Frishammar, Essén, Bergström, Ekman, 2023).

Digital health provides solutions to general healthcare needs, which includes users getting better quality of service, accessibility, and flexibility. Digital health solutions have been seen in the area of medicine such as telemedicine which uses telecommunication technologies to provide healthcare services remotely, such as video consultations with healthcare providers. Other examples of digital health solutions include wearable devices which are devices such as fitness trackers, smartwatches, and sensors that can track physical activity, heart rate, sleep, and other health metrics. Electronic health records (EHRs) are another example. Electronic health records (EHRs) contain data of a patient's medical history, diagnoses, results of tests, and recommended courses of treatment. Medical education can also be delivered digitally, providing professionals a platform to share knowledge including conferencing, virtual lecture etc. (Senbekov et al. 2020). Using wearable devices can complement other digital health solutions.

Statista estimates that there are 6.92 billion smartphone users worldwide in 2023, making up 86.3% of the world's population. Smartphones are source of communicating, and an interactive digital device (Statista, 2023). Our experience with our surroundings is affected by digital technology, specifically, digital technology has the prospect to revolutionize healthcare and boost the health and well-being of individuals and populations. (Fernandez de Osso Fuentes et al. 2023)

Digital health is a broad phrase that encompasses telehealth and may be customised through wearable technology and mobile health (mHealth). mHealth is the continuous monitoring of health using smart devices and health-related apps. During the Corona pandemic, needs for digital health has increased dramatically. The World Health Organization has a strategic plan for the year 2020-2025 about global health technology goals includes promoting healthcare systems digitally both for consumers and healthcare professionals through digital transformation to promote general wellbeing for everyone. (Joyce 2022, 709-714)

Wearable Device

The idea of a wearable device was initially proposed in 1955 by Edward O. Thorp. Edward O. Thorp happens to be a mathematics professor at the Massachusetts Institute of Technology. As a result of his proposal, scientists have created various devices that can track a person's health and lifestyle (Raad 2021, p14).

Wearable devices, otherwise known as wearables, are a rapidly growing generation of electronic devices that potentially be worn on the body and typically incorporate sensors, connectivity, and data processing capabilities. These devices are designed to enhance and augment various aspects of human life, such as health monitoring, fitness tracking, communication, and entertainment. Wearable devices use various technologies such as sensor technology, display and information feedback technology, medical chip technology, and wireless communication technology (Raad 2021, p8). These integrated technologies in wearable devices enable the health practitioner to collect a patient's health data for diagnoses. Improvements in patient experience, safety, and clinician communication for care patient documentation are enhanced through this form of digital healthcare. (Arram et al. 2022.)

Recently, wearables either as a measuring device or sensor have been used for both personal and medical use. In elderly care wearables have been used to prevent falls, to assist recovering surgical patients, etc. This work review will discuss wearable devices and more specifically, the wearable technologies available and their application in elderly care (Montero-Odasso et al. 2021).

According to Lu, Zhang and Ye, wearable medical devices are being developed for every section of the body. Application categories for wearables include maintaining health and safety, dealing with chronic illnesses, identifying and treating illnesses, and recovery. (Lu, Zhang & Ye 2020)

In today's market wearables are sold for the main purpose of measuring physical activities, how the heart functions and blood pressure, to support fitness exercise training and rehabilitation, and to detect and monitor an arrhythmia. A wearable device for healthcare use may be in the form of fabrics, patches, and vests with sensors incorporated into it, ECG patch recorders, and to achieve better prognostication and early acute decompensation identification. (Singhal & Cowie 2020.)

In the health care industry, these devices have been used to record, analyse, and regulate a person's health and to control or treat various diseases. These devices have also been used to exercise guidance on a person's lifestyle, drug administration and to provide overall human pathological and

physiological information. This information can be used by both the health practitioner and the end user. (Smarr et al. 2020.)

Lin et al. 2020 highlighted 5 major attributes of wearable devices in modern medicine which are “wireless mobility, interactivity and intelligence, sustainability and durability, simple operation and miniaturization, and wearability and portability”. The authors’ research show that a wearable device application makes use of the 4P model i.e., preventive, predictive, personalized, and participatory as it can be seen in the figure below (Lin et al. 2020).

FIGURE 1. 4P Medicine Model (adapted from Fuller-Shavel 2020)

Wearable device attached directly to human body can be used for personalized health, to record, control, analyse, and preserve health. The 4p medicine model concept emphasizes the unique need to the elderly that is personal to their health, rather than focusing on their symptoms.

Elderly

The term "elderly" is often used in the contextual relationship of healthcare and social services, as older adults may face unique challenges related to physical health, cognitive function, social isolation, and other age-related issues. Hekmat-panah 2019, stressed that aging is not a disease but a process in human life and many elderly individuals may also experience age-related chronic conditions, such as arthritis, diabetes, cardiovascular disease, and cognitive decline, which may impact their daily living activities and quality of life (Hekmat-panah 2019).

The definition of “elderly” depends on the context and the phrase is not specifically define elderly. Ageing is a process that measure age in numbers according to how long people have lived since

their time of birth (Kim, Kim 2017, 59-63). Orimo et al. 2006 state that special factors have to be considered when defining elderly according to peoples' age, factors such as region, history and their social variation. Orimo et al. 2006 stated that people live longer today than a few decades ago because of improved healthcare services, which dramatically change the meaning of the word "elderly", Furthermore the authors emphasise that the term elderly should be defined according to health status and not age alone. Orime et al. 2006, results show that elderly in Japan is classified as people over the age of 75 years who can independently live or survive on their own without or with minimum help. (Orimo et al. 2006, 149-158).

Nieto, Groba & Servia 2011 stated that the term elderly, old people, seniors, or senior citizens all refer to the same thing. The authors stated that elderly cannot be defined precisely because this meaning varies in different societies, regions or cultures. In western nations, persons that are either 65 years of age or older are considered elderly. The United Nations criterion for elderly is for persons over 60 years of age. (Nieto, Groba & Servia 2011, 12)

However, this study considers the elderly to be people over the age of 65 years, living in a service home, or with one or two ailments.

3 AIM OF THE STUDY

Aims of the study

As a result of the aging population, there is an increasing shortage of healthcare professionals globally. The aim of this thesis is to determine what wearable devices are available to the elderly population, and whether there are devices which are useful for elderly population.

Study Research questions

The following research questions below will have their solutions provided by this study:

- What is the perception of aging population on general wearables?
- Are there any specific devices available for elderly over 65?

4 METHODOLOGY AND ANALYSIS

This chapter will describe the data analysis, the literature search and methodology. The approach which research is conducted is referred to as the study design, and it includes acquiring and analysing relevant data for the research. (Kothari, 2004). It also covers the research methodology utilized to gather reliable information that served the study's objectives and gave the answers to its open-ended questions. (Kothari, 2004).

In this study, the author chooses a narrative literature review method in analysing results from the articles gathered for this study. A narrative literature review describes known knowledge about an existing topic (Ferrari 2015). The author prefers a narrative review to other types of literature review such as systematic reviews, Systematic reviews use strict methodology and search strategy. The author prefers a narrative review over systemic review because narrative review provide a broad overview of a topic, including historical background, current trends, and future directions. Additionally, it helps identify the gaps in existing evidence.

In summary, the goal of a narrative review is to provide a comprehensive overview of the literature on a specific subject, highlight knowledge gaps, and offer recommendations for future study (Ferrari 2015).

Ferrari 2015 explained that in a narrative review, the reviewer chooses pertinent research and provides a detailed summary of their findings. A critical assessment of the research methodology and quality may also be included in the review. The reviewer might examine several viewpoints and draw attention to contradictory results using the narrative technique. Ultimately, a narrative literature review may offer a useful summary of the body of research already done on a subject and serve to guide future research efforts. It is crucial to remember that narrative evaluations might be skewed by the reviewer's prejudices and interpretation of the data. Hence, it is crucial to assess the materials included in the review attentively and consider alternate perspectives (Ferrari 2015).

The process on how to do a literature search and a thematic content analysis theory are both covered in this chapter.

Data Collection

Literature search process

This study mainly focuses on wearable devices or wearable technology for elderly patients. Therefore, the search focuses on literature about this topic. The author explored the following electronic databases for relevant literature: PubMed, EBSCOhost / Cinahl Complete, ScienceDirect and Google Scholar. The search includes keywords, like wearable device or wearable technology or wearable sensor and elderly or aged or geriatrics.

The studies that discussed wearable device and health related were required to meet the inclusion criteria and were published in the last five years. Only 25 of the many articles that came up in the search will be given a thorough examination using the thematic analysis method because the dataset was limited to the years 2018-2022.

Inclusion Criterias	Exclusion Criterias
Articles and researches that language of study is in English; Articles published in the period from 2018 to 2022; Articles with quantitative, qualitative or mixed; Articles that are free of charge Articles that participants were 65 (years) or above. Articles with keyword wearables, wearable device, wearable technology or sensors, elderly, seniors, ageing	Articles that were published before 2018; Articles and research articles which language of study that is not in English Articles that the participants are under 65 (years). Articles that are paid or require payment

TABLE 1. Article selection criteria

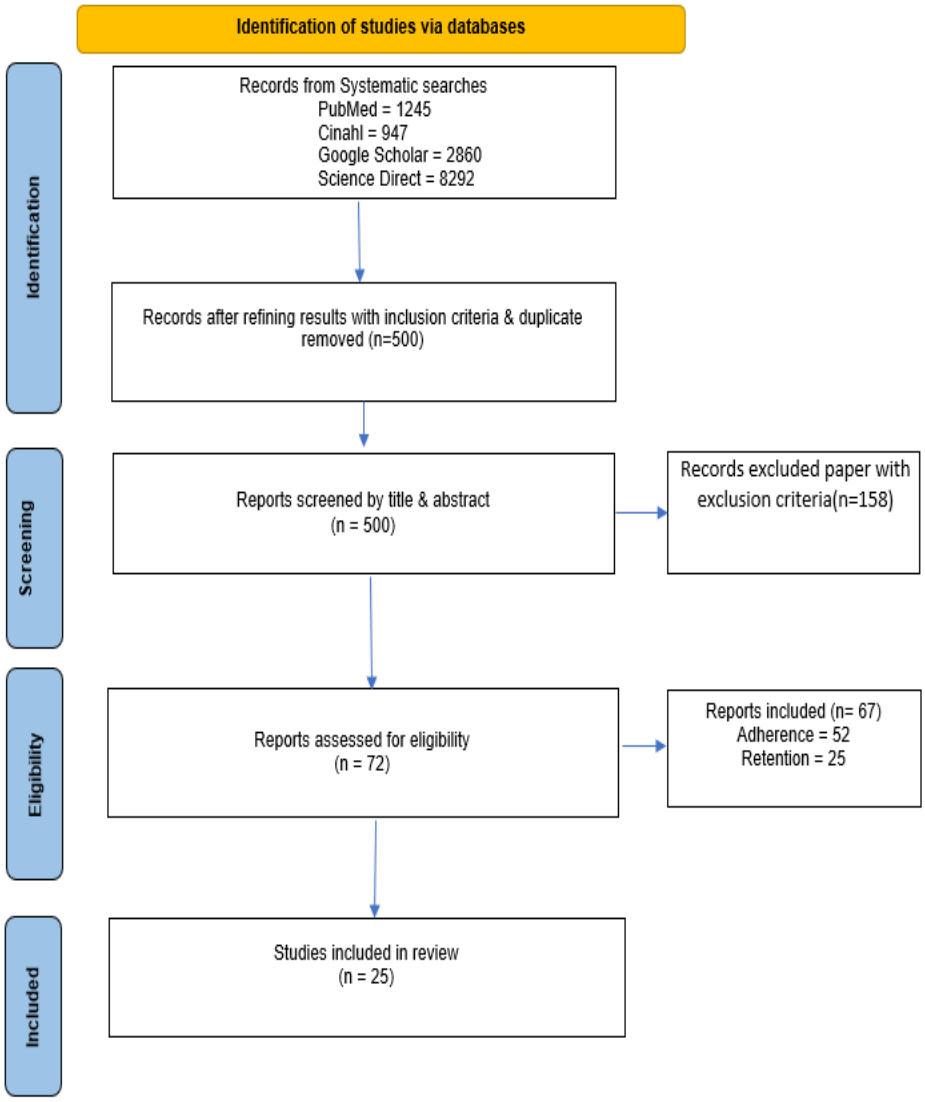

FIGURE 2. The article selection and retention process

The selection of material was limited from 2018-. Only articles written in English were selected. Articles related to wearable, sensors and elderly are highly considered and data was collected systematically. The author uses the following search terms “wearable device for elderly” or “wearable technology” or “wearable sensor”, and “elderly”. In order to limit the results, the author used the search method paired keywords with Boolean operators. The primary ideas forming the research questions served as the basis for the search terms. The search technique was developed from a number of intermediate searches, which ultimately led to the resolution of the research subject.

Most of the articles were accessed using Savonia University’s authenticated login access using the academic research databases mentioned below. By using Savonia University’s authentication login access, the author had permission to access both free and paid articles, and it also provided quality search output.

In PubMed 1245 articles were found after the criteria noted above, Cinahl with 947 articles, Google scholar with 2860 articles and finally, Science direct with 8292 articles respectively.

The inclusion criteria include articles and research in the English language, the article targeted group contains words like “elderly”, “senior”, “older citizen “and where 65 years and above, and article published between 2018 up to 2023.

The exclusion criteria exclude articles not written in English language; the article targeted age group is less than 65years, and article’s publication date is less than 2018.

Data Analysis methodology

Thematic data analysis

Thematic data analysis is a qualitative research method that involves identifying and analysing patterns or themes within qualitative data. It is commonly used in fields such as social sciences, psychology, education, and healthcare to interpret and understand the meaning, patterns, and trends present in qualitative data. Thematic data analysis requires one to become familiar with the data, arrange it according to meanings and then themes (Sundler, Lindberg, Nilson & Palmèr 2019).

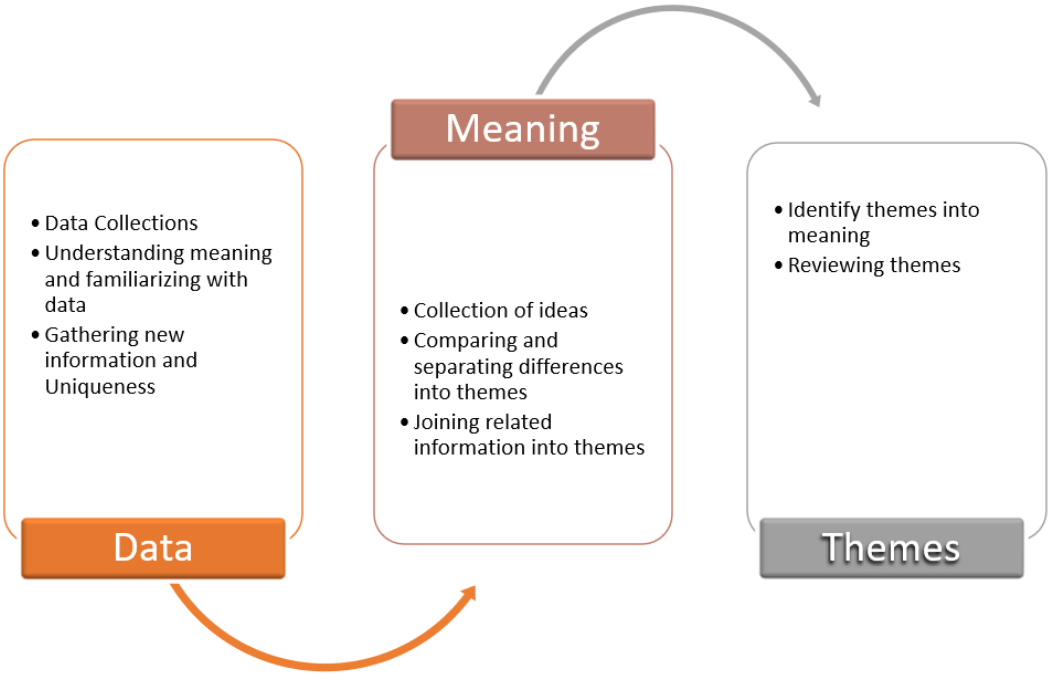

FIGURE 3. A thematic analysis idea (adapted from Sundler, Lindberg, Nilson & Palmèr 2019)

Thematic data analysis involves several steps, the figure above illustrates how thematic data analysis works and was implemented for this thesis.

Sundler, Lindberg, Nilson & Palmèr (2019, 735) explain thematic analysis by stating that

> *Analysis begins with a search for meaning and goes on with different meanings being identified and related to each other. Analysis is aimed to try to under- stand the complexity of meanings in the data rather than measure their frequency. It involves a researcher engaging in the data and analysis. Analysis contains a search for patterns of meanings being further explored and determining how such patterns can be organized into themes. Moreover, the analysis must be guided by openness. Thus, the analysis involves a reflective process designed to illuminate meaning.*

The literature that was reviewed employed thematic analysis. The author selected thematic analysis because of its flexibility on how the author interpreted selected articles. It was the best fit for this study when trying to identify, analyse and interpret the trend of wearable device usage by elderly people, and how these devices can be used for better elderly care.

However, because of thematic analysis the authors took a preliminary step by reading thoroughly the selected articles, a process known as data familiarization which falls under the data category of Figure 3 above, grouping them into themes according in other to avoid misinterpretations of data known as meaning, and then reviewing and analysing the coded data to identify over-arching themes or patterns that emerge from the data.

Thematic analysis gives deeper understanding of complex phenomena by identifying patterns and themes that may not be apparent through other research methods. It helps in generating in-depth

understanding and interpretations of the data, and can contribute to theory development, policy formulation, or practice recommendations. However, thematic analysis requires careful consideration of the context, researcher bias, and the need for validation to ensure the rigor and trustworthiness of the findings. (Sundler, Lindberg, Nilson & Palmèr 2019).

TABLE 2. Thematic data analysis

Themes	Sub-Theme	Meaning
Health Monitoring	Physical Activity Tracking	Measure steps, distance, and calories burned
	Sleep Tracking	Monitor sleeping quality and duration
	Heart Rate	Measure heart rate in real-time
Health Safety Support	Personal Emergency Response System	Detect fall, quick help in case of emergency
	Medication reminder device	Alarm like medication reminding device
	Hearing aid system	Support communication
Wearables Challenges	Perceptions	How elderly feel about wearables
	Privacy concerns	Worries about personal information
	Interoperability	Ability for wearables to communicate with other devices

The results from the table above classify the importance of wearable devices using Thematic data analysis. Thematic analysis can be used to provide insights by grouping themes, sub-themes and meaning.

5 RESULTS OF RESEARCH

Boffetta and Collatuzzo 2022, researched the use of 4P (Predictive, Preventive, Personalized and Participatory) method to workplace safety and wellness. The authors argue that the 4P approach can help to address the unique challenges of occupational health, such as exposure to workplace hazards and the development of work-related illnesses. Boffetta and Collatuzzo 2022, suggests that by utilizing P4 technologies such as genomics, proteomics, and metabolomics, occupational health practitioners can predict an individual's risk for work-related illnesses, personalize treatment plans based on that risk, and prevent disease before it occurs. Additionally, digital health technologies such as wearables and mobile apps can be used to monitor worker health and identify potential health problems quickly. The authors stress the necessity of a participatory approach to workplace safety and wellness, which includes actively engaging workers in their own health management. An example of this in my current work includes my employer allowing me to choose any private hospital to monitor my overall health. This may be accomplished through educational programs as well as the use of digital technologies that allow employees to track their health data and receive individualized health recommendations. Overall, the article suggests that the P4 approach has the potential to revolutionize occupational health by allowing for a more personalized and proactive approach to health management, which might enhance worker safety, reduce expenditures on healthcare, and eventually contribute to a healthier workforce (Boffetta, Collatuzzo 2022).

Fuller-Shavel 2022, also researched 4P model for patient with one or two exiting diagnoses. The authors argue that while the P4 method is primarily focused on illness prevention and prediction, it can also be beneficial for patients who are currently coping with a diagnosis. According to Fuller-Shavel 2020, the P4 method may be used to tailor treatment programs based on a person's unique genetic, environmental, and lifestyle characteristics. By analysing this data, physicians can gain a better understanding of the root cause of a patient's ailment and develop tailored therapies aimed at addressing those causes. The authors stress the significance of a participatory approach to healthcare, in which patients actively participate in their own health management. This may be accomplished by utilizing digital health technology such as wearables and mobile applications that enable people to track medical information about them. Overall, the article suggests that the P4 approach has the potential to revolutionize healthcare for patients with existing diagnoses by enabling a more personalized and proactive approach to treatment that can improve outcomes and quality of life (Fuller-Shavel 2022).

The author reviewed the 4P medical model in explaining the benefits of wearable devices available for elderly. The 4P medical model refers to a framework used in healthcare to understand the different aspects of health and wellness. The 4P medical model with wearable devices refers to a framework that encompasses four key elements - Predictive, Preventive, Personalized, and Participatory to improve elderly care outcomes using wearable devices.

Prediction: Fuller-Shavel 2002, using prediction to involves using data and technology to predict health outcomes and identify potential health risks before they manifest. Wearable devices, such as fitness trackers, smartwatches, and health monitors, can collect a wide range of data, including heart rate, sleep patterns, activity levels, and more, which can be used to create or predict health related issues. Wearables can collect real-time data on an individual's health state such as falls, sleep or location in case of missing, allowing for the prediction of potential health concerns before they become serious. By analysing this data, healthcare providers can detect patterns and trends that may suggest the development of specific ailments in the elderly, such as cardiovascular disease, diabetes, or sleep disturbances, and take preventive actions to control or mitigate them (Fuller-Shavel 2020).

Prevention: Fuller-Shavel 2002, using prevention with wearable devices can empower elderly to take proactive steps to prevent health issues by promoting healthy behaviours and lifestyle changes. Based on the predictions made, wearable devices can be used to implement preventive measures to avoid or reduce the risk of developing health issues. For example, fall, medication reminder wearables or if a wearable device detects a rise in heart rate during physical activity, it may alert the wearer to take a break or slow down to prevent overexertion and potential heart problems. It can also encourage regular physical activity, monitor nutrition and hydration, and track medication adherence. They can also provide feedback on behaviour patterns and offer personalized recommendations for improving health outcomes. By promoting preventive measures, wearable devices can help individuals reduce the risk of developing chronic diseases and maintain overall well-being (Fuller-Shavel 2020).

Personalization: Fuller-Shavel 2002, describe personalization of health using wearable devices enable personalized healthcare by tailoring interventions and treatments to an elderly specific need. Using this model shows that through continuous monitoring and data analysis, wearable devices can provide insights into an elderly’s unique health profile, including physiological, behavioural, and environmental factors. This information can be used to create personalized healthcare plans, interventions, and treatments that are tailored for personal needs, preferences, and goals. For example, wearable devices can provide personalized exercise plans, nutrition recommendations, and medication reminders, taking into account an individual's health history, lifestyle, and other relevant factors. For instance, a wearable device may analyse a person's sleep patterns and provide suggestions on how to improve their sleep quality based on their specific sleep habits (Fuller-Shavel 2020).

Participation: Wearable devices can empower individuals to actively participate in their own general wellbeing by engaging them in monitoring and managing their health. This can include setting health goals, tracking progress, receiving notifications and reminders. Wearable devices can also facilitate communication and collaboration between patients and care givers, allowing for remote observation or monitoring, virtual consultations, and telemedicine services. This participatory approach promotes patient engagement, self-care, and shared decision-making, leading to better health outcomes (Fuller-Shavel 2020).

Overall, the 4P medical model with wearable devices emphasizes the use of data-driven predictions, preventive measures, personalized interventions, and active participation to promote proactive

healthcare and wellness management. By leveraging wearable devices, individuals can have better insights into their health, make informed decisions, and take proactive steps to optimize their well-being.

5.1 Elderly perception about wearable device

Wearable devices have appeared to be a solution in supporting and providing innovative care for an elderly population, however, studies show that this group shows slower adaption of technology compared to younger adults (Yap, Tan, Choon 2022).

Yan, Tan and Choon 2022 conducted research on the senior population's adoption of technology. The authors determinants of adoption were divided into seven key areas in their study, including technological, psychological, personal, social, cost, behaviour, and environment. The authors used a systematic review with a total of 26 important articles where 9 of the articles were related to technology in healthcare. Seven categories were used in the study to understand the elderly population's adoption of technology, these include cost of goods and services, social, psychological, personal, and technological factors. A summary of their research shows more factors affect adaptation of wearable devices by the elderly (Yap, Tan & Choon 2022).

The authors also pinpoint behaviour as the main factor influencing technology adoption for the elderly and suggested that further research should be made to understand adoption behaviour of technology challenges for the elderly (Yap, Tan & Choon 2022).

Studies have shown that older adults have developed interest in wearables for their personal health. Kekade et al. study addresses the accessibility of wearables among elderly population. The primary goal of the work was to analyse the advantages of wearables. The authors use a systematic review and a survey questionnaire to determine whether elderly people are interested in wearables, the study had 1100 participants, 54.3% which were over 65 years while 45.49% where less than or equal to 65 years. The study indicated that older adults or elderly adults are interested in wearable devices. The sample result also shows females were more interested in using wearables than their male counterparts (Kekade et al 2018).

Kekade et al. concluded that only relatively few members of the elderly population are using wearable devices or technology today because of lack of awareness. In their research they stressed that improving physical and mental activities by monitoring using wearable device gain the interest of over 60% of the elderly, however, more information about the availability and use of wearable devices among elderly population is not known (Kekade et al. 2018).

Li, Ma, Chan & Man 2019, developed a smart wearable acceptance model for adults over the age of 60 years. The model was generated from 146 potential users with no previous use of wearables. Unified theory of acceptance is known as the UTAUT. The study employed both the TAM (Technology acceptance model) and the unified theory of adoption and usage of technology. Technology Acceptance Model has emerged as one of the most prominent models of technology adoption, which stated that two major elements affect a person's desire to accept new technology. These are how

easy to use is the technology to use, and what usefulness does the technology provide. The result shows older adult perception about wearable devices are positive. The authors indicated other factors that contributed to the adult interest in wearables were 1. Adult health status, 2. Compatibility of the device, 3. Facilitating conditions. The author contribution suggested broader acceptance of wearables in elderly care needs effort from healthcare practitioners to create awareness of wearable devices (Li, Ma, Chan & Man 2019).

5.2 Available wearables

Many young and middle-aged citizens use wearable devices particularly for personal health monitoring and wearable devices have also been used for elderly care. Guk et al. 2019 define wearable devices as a biosensor that is non-invasive that measures human activity signs and vital signs in real time for nonstop monitoring. The authors classify wearables into rings, glasses, clothing, contact lenses and bandages. (Guk et al. 2019).

Guk et al 2019 stated that wearable devices are “portable devices can be classified as wrists (watches, bracelets and gloves), heads (glasses and helmets), body clothes (coats, underwear and pants), feet, and body sensory control devices (somatosensory modulators)”. Examples of these wearable devices are smart watches, fitness trackers (Guk et al, 2019).

Dunn, Runge & Snyder 2018, in their study stated wearable devices available for medical purposes uses biochemical sensors, which have both internal and external chemical sensors for monitoring. The authors stated that some wearables are integrated for general healthcare practice, additionally, they classify wearable sensors into three major categories mechanical, physiological and biochemical. These are the applications that are commonly used for clinical applications of wearable device. (Dunn, Runge & Snyder, 2018).

In their study, Lobo et al. 2019 define wearables as an object that monitor movements with the help of smart device. According to the authors, wearables can be divided into three categories wearables 1. Wearables integrated clothing (such as alterations in fit and closures); 2. Supportive devices like exoskeletons and orthotics; and 3. Smart wearables, such as those equipped with sensors for controlling external devices or tracking activity. (Lobo et al. 2019)

Below is the list of wearables devices in elderly care.

Personal emergency response system (PERS) is a wearable device that is frequently in the shape of pendants or bracelets and enables elderly people to get assistance in the event of an emergency. They can link to a monitoring center or a designated caregiver who can provide aid with the touch of a button, making them suitable for elderly living at home or at a service home who are at danger of falling. An example of this device can be found in Finland among elderly with home care service called home protection. This wearable makes use of ultra-sonic waves to detect changes in motion and orientation and can automatically send alerts to caregivers or emergency services when a fall or emergency is detected. The system has the potential to provide an effective

and non-intrusive solution for monitoring and responding to emergencies, especially for elderly or vulnerable individuals who may require assistance in case of a fall or other medical event. (Regev, Wulich 2020). Stokke 2016, highlighted the potential of PERS in enhancing safety, reducing hospitalizations, improving quality of life, and promoting aging in place for older adults. The author also discusses challenges and limitations of PERS, such as false alarms, user acceptance, and cost considerations (Stokke 2016).

Medication reminder devices address medication non-adherence is a common challenge among the elderly. Wearable medication reminder devices can provide timely reminders to take medications, track medication schedules, and send alerts to caregivers or family members if a dose is missed. These devices can come in the form of smartwatches, bracelets, or other wearable formats (Majumder et al 2017).

Hearing aids wearables help the elderly who have diminished ability to hear. Smart hearing aids with built-in wearable technology can provide advanced features such as connectivity to smartphones, personalized sound settings, and remote-control options. These devices can enhance hearing capabilities and improve communication, helping seniors stay connected and engaged in their daily activities (Majumder et al 2017).

GPS tracking devices is a device use technology that can help caregivers or family members keep track of the location of elderly individuals who may have cognitive impairments or are at risk of wandering. These devices can be worn as watches, pendants, or attached to clothing, and provide real-time location information, allowing caregivers to locate their loved ones and ensure their safety. A very good example of these devices are the general smart watches that are embedded with location navigation system. Fall detection devices are wearable devices that use sensors to detect falls and automatically alert caregivers or emergency responders. They can be worn as pendants, bracelets, or clips, and can automatically detect sudden movements or changes in orientation that may indicate a fall, providing prompt assistance to the elderly in case of a fall-related emergency (Majumder et al 2017).

5.3 Application of Wearable device

Wearables used prevention of Falling

One of the most common risks injuries with elderly people over 65 years of age is falling. Kulurkar et al. 2023 investigated wearable devices used to recognize the detection of falls in indoor circumstances, real-time tracking of elderly activities, and fall detection using the LSTM fall classification algorithm. MetaMotionR, is a brand of wearable sensors from MbientLab, which provides precise data to an edge device. An edge device is any device that regulates data flow at the dividing line between two networks. The authors utilized a laptop as the network edge to analyse the stream

sensor data and built up an automated pipeline analysis utilizing special APIs from MbientLab, Apache Flink, and TensorFlow (Kulurkar et al. 2023).

Kulurkar et al. 2023, shows that wearable devices worn on both waist and wrist generate highly reliable output compared to wearables worn on other parts of the body in detecting falls. The authors carried out four different type of fall scenarios to generates 65 sets of falls, the frequency used on the wearable devices were 12.5, 25, 50, 100 and 200Hz respectively. 50Hz was the optimal frequency in terms of accuracy. When there is a huge change in frequency up to 200Hz, this implies a fall has occurred. The 2023 study by Kulurkar et al. 2023 suggested that the elderly, who are more likely to fall, can benefit from better care by using a wearable fall detection device. The LSTM model device shows 99% accuracy in identifying falls based on actual sensor data (Kulurkar et al. 2023).

Wu et al. 2022, research fall risk assessment for elderly over a continues occurrence decency interval by the way they walk called gaits, which detect plantar pressure. Wu et al 2022, demonstrated MhNet which is a neural network architecture that is designed to denoising, deblurring, and produce a super-resolution picture of a restoration jobs. MSTHNs leverage the hierarchical nature of spatio-temporal data, where information at different scales and levels of abstraction is present to

improve performance and efficiency. They typically consist of multiple layers that are organized hierarchically, with each layer responsible for processing information at a different scale or level of abstraction. MhNet has adequate results in actual-time fall risk assessment utilizing just 9 gaits, accuracy is between 72% to 75.20% in sensitivity using a frequency of 20Hz, when compared to older approaches such as LSTM, AlexNet, DG-DANN and VggNet-16. MhNet offers the ability and application possibilities to detect older people who are at high risk of falling. Wu et al 2022 suggested that a wearable device needs to be used by elderly for longer period of time in other to achieve its full potential, additionally, wearable devices are currently and in the form of mobile phones, bracelets, bands and other forms, and are not used as often as they could be because of the relatively high price of these devices. (Wu et al 2022).

Nie, Xuan & Ren 2021, researched falls and walks in the elderly and suggested a wearable device using an antenna with EBG bandgap frequency of 2.45GHz. When falls occur, pressure is been generated from the ground into the antenna. Nie, Xuan & Ren 2021, recommend wearing this sensor on either on the elbow or knee, and also emphasize EBG can protect the human body from radiations (Nie, Xuan & Ren 2021).

However, there is a contradiction in Kuluekar et al. 2023 and Wu et al. 2022, Wu et al. 2022 stated that MhNet is far better in predicting elderly fall with accuracy of ~75% compared to LSTM, while Kuluekar et al. 2023 show 99% accuracy with LSTM network technology.

Wearables in Orthopaedic

Orthopaedic focuses on treating injuries and conditions affecting the musculoskeletal system, which includes the knee, hip, ankle, and shoulder joints as well as skeletal muscle, bone, cartilage, and the spine. Wearable devices have been introduced for the elderly for monitoring and personal treatment. According to Yu et al. 2022, in the diagnosis, treatment, and post-rehabilitation monitoring of orthopaedic illnesses, wearable technology has a wide range of potential applications. Yu et al.

2002, found that the difficult charging and short service life of batteries severely limit the long-term uses of wearable technology. Nanogenerators (NGs) are positive energy converters that may turn the biomechanical energy produced by everyday activities into electricity. Additionally, the gadget may be used as a self-powered sensor in addition to providing energy.

Yu et al. 2002, stated in their work that wearable device nanogenerators in orthopaedics applications are flexible film and brace integrated into the insole and socks which measure the joint motion and gait. Flexible films also measure the muscle function. Textile sensors that are wearable and developed inside cloths may be used in rehabilitation and cardiovascular monitoring. Mask wearables for respiration monitoring and body temperature also uses flexible film.

Zhang, Sun & Chen 2022, stated in their study that the attributes of wearable devices are wearability, flexibility, continuity of time and diversity. Zhang, Sun & Chen 2022, researched rehabilitation and the monitoring of cartilage damage with wearable devices. The authors' study evaluates devices that use electrotherapy to help repair damaged tissue with the combination of strength exercise.

Wearables in Home care

The World Health Organization (WHO), estimated that in low- and middle-class countries there will be about a 10 million healthcare workforce shortage by the year 2030 (WHO 2023). In Finland, the shortage of healthcare professional needed by the year 2030 is estimated to be around 200,000. (YLE News 2022). It is important to note that the strain on healthcare workers over past years has increased dramatically. It is increasingly believed that introducing wearables in home care will ease the burden on healthcare providers and will likely help the elderly to become more independent. Lv et al. 2020, evaluated the YuMi robot, which is an assisting wearable device used in elderly care for patients with dementia. In their study, the wearable device is separated into a robot control subsystem and a human motion capture subsystem, allowing healthcare providers to perform an action, and then this action is then transferred into the YuMi robot allowing the robot to perform the task according to the carer's instruction. According to Lv et al. 2020, this wearable device provides support for adult with dementia to be more independent, making caregiver's work easier with low training cost (Lv et al. 2020).

Murphy, Holmes, & Brooks 2017, evaluated wearable device called Sensewear Armband, to measure in the elderly with dementia physical activity, sleep, and energy consumption. In their study this device was positioned on all participants' upper left arm. As a result of using the Sensewear wearable, the authors stated that this wearable can be used for a personalized dietary management for elderly, which in the long run may help reduce unnecessary weight loss in elderly with dementia, and additionally help care givers monitor sleep quality and activity levels (Murphy, Holmes, & Brooks 2017).

Another challenge with the elderly at a nursing home includes elderly with limited mobility who tend to stay in wet diapers for a long period of time causing pressure ulcers. Baek 2023, discussed a wearable device monitoring model based on multi-sensor IoT called Diaper Care Device, using a combination of sensors including temperature, humidity, VOC gas sensors for elderly with limited mobility. This wearable device is attached to a diaper and will detect urine, faeces, or flatulence,

and additionally it can also detect current posture of a user giving care givers an idea on how long the person has been in a position as a means of detecting a fall (Baek 2023).

Wearables in Rehabilitation

Wearables have been used in rehabilitation. Biochemical and physiological monitoring, together with motion sensing, are now capabilities of wearable devices. The scope of the issues that wearables may assist or address cannot be overstated. People with neurological, cardiovascular, and pulmonary illnesses such seizures, hypertension, dysrhythmias, and asthma have benefit from physiological monitoring for both initial diagnosis and continuing care. Wearable devices available for use in rehabilitation for elderly with stroke is a smart cloth and a smart chair which has the capacity of measuring physical activities such as motion and also have the capacity to generate heat to warm up the body. Likewise, for elderly with rheumatoid arthritis which is a condition with a chronic inflammatory of one or more joints of the bone, Bravo & Muñoz 2022, presented a smart glove with finger sensor that help elderly with movement and help with medication monitoring (Bravo & Muñoz 2022).

5.4 What do wearable devices for the elderly measure?

According to Guk et al, 2019 wearable devises measure cardiovascular signals, sweat contents, salivary content, physical activities, and physiological signals (Guk et al, 2019). Table 2 shows the types of wearables, what they monitor, and physiological & physical parameters.

Kulurkar et al. 2023, stated wearables are worn on the wrist, thigh, calf, side waist and chest when used to detect fall in elderly.

Wearables	Device example	Monitoring	Physiological & Physical parameters (Device)
A Wrist Devices	Belt, fob, band, watch	Cardiovascular signal Sweat content	heart rate, blood pulse, etc glucose, sodium etc.
Head mounted	Cap, eyes, glasses, ears	Salivary contents Sweat contents Cardiovascular signal	lactate, uric acid and glucose Lactate and potassium heart rate
E-Textiles	Sock, Shirt, jacket	Sweat contents Physical activity Physiological signal	Glucose, lactate, heart rate Temperature, foot motion
Others,	Ring	Physical activity Physical activity Physiological signal	Sleep, daily activities-Steps, ECG

TABLE 3. Wearable devices, what they measure, what device (Adapted from Guk et al, 2019)

As it can be seen from the table above, most available wearables measure physical activity and cardiovascular signal.

5.5 Benefit of wearables for elderly

Wearable devices can help monitor numerous health parameters such as blood pressure, heart rate, and sleep patterns, among others which also track physical activity levels, which can be useful for promoting exercise and maintaining mobility among seniors (Singhal & Cowie 2020.)

Wearable devices can identify, reduce, and prevent falls according to Wu et al. 2022. When a fall is prevented quality of life improves. Using wearables by elderly support healthcare professionals to do their task without fear as a result of wearable device informing them in case a fall occurs. In remote monitoring wearable devices helps the elderly get required quickly help when falls occur (Wu et al. 2022). Wearable devices are used in rehabilitation for orthopaedic patients (Yu et al. 2002).

Murphy, Holmes, & Brooks 2017, discussed the use of wearables in monitoring sleep, physical activity and nutrition management in elderly with dementia. These devices help care givers follow up on how to balance elderly food intake and outtake preventing weigh loss (Murphy, Holmes, & Brooks 2017). Wearables for those with dementia give the elderly a supporting edge to be independent in his or her home/care home. With the help of YuMi robots additionally, wearable devices can be used in reminding elderly to take their medication on time. This can help prevent missed doses and ensure that seniors are taking their medications as prescribed (Lv et al. 2020).

In general, the use of wearables in elderly care can improve the quality of life for elderly and provide caregivers with valuable insights into their health and wellbeing. It can also reduce cost due to avoidable hospitalizations.

Wearable devices available for the elderly include smartwatches, fitness trackers, GPS tracking, hearing aids wearables and medication reminder systems. Smartwatches and fitness trackers can monitor physical activity, heart rate, and sleep quality, as well as provide medication and appointment reminders. However, the author believe smartwatches and fitness trackers can be used by anyone of any different age.

6 DISCUSSION

Any electronic equipment that is intended to be worn on the body is considered a wearable device. Wearable technology assists in the real-time collection and analysis of personal data that teaches users about health-related information and uses a sensors or other technologies such as AI, ML big data and Iot. Wearable devices come in form of accessories: watches, bracelets, clothing such as vests, sweaters, shoes etc (Ahmad et al. 2020).

This study provides and supports the use of wearable device in elderly care in service homes, and it also gives a general idea about what types of wearable devices that are currently available in the market today for healthcare use. The author discusses the available wearable devices specifically for elderly such as PERS, medication reminder device, hearing aid device and GPS tracking device. It is good to take note that these devices might have different makers and come in different forms. No specific name or specific product is mentioned in many research papers, and this might be a result of authors not wanting to be seen as advertising, marketing, or promoting any wearable devices in their research work.

The results show that the use of wearable devices can be the future of healthcare in the monitoring and accessing elderly remotely, and be used in home care especially when wearables are exploited to their full potential.

The pace in which technology evolves and the ability of elderly to adapt to this change is a challenge that requires training and motivation.

Wearable devices have been gaining popularity globally, including in developing countries. These devices, as it has been mentioned during the entire thesis, provide a range of potential benefits to positively impact human lives regardless of age. The author regards developing countries or countries with relatively low per-capita income and countries where the access to healthcare is limited as places with a major population of unsupported ageing population.

Another application of wearable devices in developing countries might be in disaster management such as earthquakes and emergency response. For example, wearables with location tracker can help emergency personnel more effectively find missing elderly people.

Wearable devices will make a significant difference in developing countries however, there might be some obstacle hindering the development. Using Nigeria as a case study, the author will briefly discuss below his personal experience with that society and the cultural issues affecting adoption of wearable digital devices for the elderly there.

Wearables in Emerging Economies Using Nigeria as an Example

In developing countries, the wearable device concept in supporting elderly might be a new innovation compared to developed countries like the United States, United Kingdom, or Finland. A developing country like Nigeria is slowingly adapting to the use of technology and emerging technology trends. Various obstacles may hinder the usage of wearable technologies in this region.

Nigeria is a West Africa country, with a population of approximately 250 million people and over 250 ethnic groups. Nigeria's inadequate healthcare system remains a big concern, as seen by high morbidity and death rates. In Nigeria, the government provides the majority of healthcare services. However, non-governmental organizations (NGOs), business minded organizations, traditional

healthcare providers, and community-based groups are all examples of healthcare service providers. (Mooshood et al. 2022). Generally, many Nigerians believe that it is the responsibility of a child or children to take care of their older relatives, therefore using a wearable device in monitoring an elderly relative's health related issue can be an added advantage. Life expectancy in Nigeria for men is 59 years while 63 years for women, significantly lower than in more developed regions of the world.

Factors that might encourage the adaptation of wearables in Nigeria include the fact that many people die at a younger age because of avoidable circumstances, cultural differences, and other barriers. Nigerian communities are close, family members tend to care for each other. Children traditionally care for their elderly parents. A few service homes for the elderly have been established during the past few years but lack of patronization has made most of these start-ups close down. Lack of patronization is likely a result of inadequate resources or money to pay for services. Lack of infrastructure such as a reliable power supply and unreliable internet connections also play a major challenge in the adoption of wearable devices in Nigeria. The cost of wearable devices might limit elderly use of wearables.

The elderly population in Nigeria faces unique challenges as stated above, such as limited access to healthcare and limited mobility. With financial help, wearable devices could provide a cost-effective and accessible way for elderly to monitor their health, stay active, and improve their overall well-being.

Wearables Privacy Concerns

Brannon, Mitchell & Liao 2022, discussed in their studies privacy concerns about mobile and wearable devices with a cancer survivor adult. Brannon, Mitchell & Liao 2022 stated general concerns about privacy include security of personal information, data valuation, sharing of personal information, autonomy, permission, ownership i.e., who owns the information gathered from a wearable device (application provider or user of the application), and access to data. The authors stated that concerns about wearable devices are extremely low, and most users are not concerned about their data being misused (Brannon, Mitchell & Liao 2022).

Javdan, Ghasemaghaei & Abouzahra 2023 studied the psychological barriers influencing the elderly population's willingness to use a wearable device. The authors concluded that both cognitive and motivational barriers are factors propelling elderly away from using wearable devices. Cognitive barrier is defined by Javdan, Ghasemaghaei & Abouzahra 2023 as age-related deficiencies, because some elderly persons may have reduced cognitive capacity levels. These deficiencies cause some elderly to have less attentional resources and cognitive control, which has a detrimental impact on reasoning and memory skills. Understanding and memorizing the procedures to complete a certain activity when utilizing a new technology in particular need logic and memory. As a result, elderly persons with severe cognitive deficits regard themselves to be incapacitated. Elderly with perceived limitations have a poor assessment of their health state, and this may affect their capacity to

engage satisfactorily with wearable technologies. This motivational barrier may create frustration and the unwillingness to learn the use of new technology (Javdan, Ghasemaghaei & Abouzahra 2023).

The battery longevity of wearable devices cannot be overlooked. Wearables' battery life has developed over the years. However, wearable device batteries life is causing chaos in the industry. The battery life of wearable devices can vary widely depending on several factors such as the type of device, the brand, the features it offers, and how it's being used. Generally, smartwatches and fitness trackers have battery lives that range from one day to a few weeks. Smartwatches with more features like GPS and cellular connectivity tend to have shorter battery lives, often requiring charging every day. On the other hand, basic fitness trackers that only track steps and sleep can last up to a few weeks on a single charge. Other factors that affect battery life include the screen size and resolution, the type of display (LCD or OLED), and the type of battery used. Some wearables also offer battery-saving modes that can extend their battery life by reducing features and turning off certain functions (Yang et al 2021).

Limitations of study

There are several drawbacks to this study. One of the limitations is the selection of articles for this study, also search criterial might also affect the selection of the research work. Secondly, the words "wearable device" was used interchangeably with "wearable technology" or "wearable sensor" among different articles which could potentially affect end results. The author was not able to review articles that are not in English, and research in other languages may have been benefitted this study.

The author would also like to point out that many articles used during this study do not promote or provide information about any specific wearable device used in elderly care. Most of the wearable devices mentioned were commonly known gadgets such as Fitbit, Apple Watch etc. Therefore, the author acknowledges that this study does not address all the different wearables available in today's market. Additionally, because of the rate at which technology is evolving there are likely more new wearables coming into the market in the near future.

The author's time constraints would possibly be a limiting factor that affects this research work.

Regardless of the limitations, the author believes that the narrative literature review still provides valuable guidelines and understanding pertaining to use and embracing of wearables by elderly with the quality search and transparent data analysis.

Ethical considerations

The scope of this study primarily focuses on a narrative literature review, and the author does not process directly sensitive personal data. However, ethical considerations were taken into consideration throughout the study and the author act in accordance with the rules of the Finnish Advisory Board on Research Integrity (TENK).

During this study, ethical practice, reliability and transparency under the ethical limitations were taken into consideration. Critical selection of study material and reading was applied through the study.

Ethical consent is considered in this thesis work. This thesis takes into consideration and does not share any sensitive information that might harm anyone including elderly which was the main content of this thesis work. During data collection the author use a clean data collection that the information gathered might not be used in identifying anyone, such as their names, social security numbers and addresses. Additionally, professional language was used in other to remove biased statements that might harm any elderly gender or nationality.

Reliability and validity according to Golafshani 2003 is the degree a measurement of a phenomena yields a steady and consistent result over time. While validity, on the other hand, is define to the extent to which a measure actually measures (Golafshani 2003).

The author searched for relevant related articles using the following electronic databases for relevant literature: PubMed, EBSCOhost / Cinahl Complete, ScienceDirect and Google Scholar. The search included keywords, like wearable device or wearable technology or wearable sensor and elderly or aged or geriatrics in this thesis work. Criteria selection such as selecting articles only in English, articles published between 2018 to 2022, articles with qualitive, qualitative or mixed research methods and finally, participants were elderly 65years or above, and this helped the author to minimise the search results. The author made sure in the selected articles wearable devices were the key target of discussion and relevant to the research topic. The author used a thematic data analysis to answer the research questions and support the result using the 4p model. Finally, the author strongly believes that this thesis work does not harm anyone either physically. socially or psychologically.

This thesis is not sponsored by anymore or any organization neither do the author has no conflict of interest in this study.

7 CONCLUSION

This thesis studies the use of wearable devices available for elderly care. The study shows the importance of wearable devices for elderly care. It also analyses the adaptation and adoption of wearable devices by the elderly or senior citizens. Yap, Tan, Choon (2022) stated that the elderly is also interested in wearable devices in the same way as a younger adult. The major importance of wearables for healthcare includes an ageing population and cost of treatments and care. A wearable device could be used in elderly care to prevent harm, improve personal care, educate, and reduce the workload on healthcare professionals.

Wearable devices have emerged as a promising technology for improving the healthcare and well-being of elderly individuals. Wearable devices usage in caring for the elderly population has shown great potential in various areas, including fall detection, activity monitoring, medication management, and remote monitoring. These devices provide valuable data that can assist healthcare

providers and caregivers in identifying health risks, managing chronic conditions, and providing timely interventions.

These wearable devices include the well-known fitness trackers such as the Fitbit, Apple Watch, Samsung, and Galaxy Fit that gather information on physical activities like the number of steps taken, numbers of burnt calories, sleep quality, and heart rate to more advanced gadgets that can gather data on blood pressure, blood sugar levels, and saturation (Chandrasekaran, Katthula, Moustakas 2022).

Wearable devices make remote monitoring easier allowing caregivers and family members to monitor their loved one's health and well-being. Wearables can monitor vital signs like blood pressure and pulse rate, spot falls, access sleep data, physical activity and even remind the wearer to take their prescriptions. Some wearable devices also have GPS functionality, which can be used to track the location of the wearer in case of wandering or disorientation. Additionally, some devices have communication features that allow the wearer to contact caregivers or emergency services if needed. These wearable devices can promote the independence of the elderly, allowing them to live at home for longer and avoid unnecessary hospitalizations or institutional care.

Other wearables device such as PERS is also discussed which is a wearable or home-based device that enables individuals to call for help during emergencies.

In this study, most articles about wearable devices used for elderly care discussed the types of technology used for wearable devices such as IoT, AI, ML etc. However, most wearables used in elderly care are implemented in mobile device and watches. The author believes most of these wearable devices for elderly can also be use by other age groups such as young adult or by working class citizen. Wearable devices are not a replacement for healthcare professionals, but a valuable addition to it, allowing caregivers to track the well-being and general health of older adults remotely.

However, to ensure the successful implementation and widespread adoption of wearable devices in the elderly population, several considerations must be addressed. These include addressing interoperability, privacy concerns, affordability and appearance play a major challenge to today's wearables and should be considered. Hale, Lotfy, Gamble, Walter & Lin (2018) stressed the fact that misuse of wearables may cause a fatal disaster for both organizations and end-users. To address this risk, stakeholders and governments should setup standards and regulations in tackling this issue. Elderly users' privacy and data protection should be a necessary requirement.

Wearable devices have the potential to bring significant benefits to elderly population globally but in however, in developing countries challenges related to cost, infrastructure, privacy, and cultural factors need to be addressed to ensure the effective and ethical adoption of wearable devices. With proper planning, customization, and collaboration among stakeholders, wearable devices can be powerful tools for positive change in developing communities, improving the lives of people and contributing to sustainable development.

Despite these challenges, wearable devices hold immense promise in supporting elderly individuals to age in place, maintain their independence, and enhance their overall quality of life. As technology

continues to advance and wearable devices become more accessible, reliable, and user-friendly, they have the potential to revolutionize healthcare for the elderly population.

Answering the research questions about on what is the perception of aging population on general wearables? The researched articles shows that most elderly are willing to adopt wearables devices as a tool for promoting personal health. However, there is resistance due to concerns about privacy, security, and usability issues regarding certain types of wearables such as activities trackers and GPS trackers.

The research second question on whether there are any specific devices available for elderly over 65 years shows that devices such as Personal emergency response system (PERS), medication reminder, hearing aids and GPS trackers are meant for the elderly population. However, there are many other wearables such as steps tracker, GPS trackers designed for everyone regardless of their age. These and can be used by elderly, but the issue of usability should be considered, and this was not discussed in this thesis work. The author suggests wearables with feature larger displays, simplified interfaces, and unique features such an emergency quick button could be a good usability features for the elderly. As the elderly population continues to grow, the development of wearable technology that meets the needs and preferences of this demographic will become increasingly important for promoting healthy aging and improving quality of life.

Further research related to the topic on wearable device availability for elderly should focus more for an example how to encourage wearable device adoption in developing countries, taking into consideration life expectancy, social economic factors, and how culture influences the use of wearables. Additional research on devices available and how practitioners' use this data for their clinical use are also important topics for ongoing research.

Further research addressing availability, acceptance, and usability of wearables in developing countries must be done to ensure the widespread adoption of these devices. When designing wearable devices for the elderly, IT engineers and user UX designer should consider elderly specific needs and limitations. For example, seniors may have vision and hearing impairments, limited mobility, and difficulty using complex technology. To address these issues, wearable devices must be user-friendly, with larger buttons, high contrast displays, and intuitive interfaces.

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9 APPENDIX

APPENDIX 1. Below are some examples of health-related wearable devices

FitBit: Count steps

Website- https://www.fitbit.com/global/us/products/trackers

FitBit ()

Apple Watch: Measure saturation, track, sleep quality, an electrocardiogram (ECG), sensor, fitness trackers and overall heart health monitoring.

Website- https://www.apple.com/fi/apple-watch-series-8/

Apple Watch 8 (Apple)

Omron HeartGuide: Blood pressure and fitness trackers

Website- https://omronhealthcare.com/

HeartGuide

Xsensio: Using cutting-edge nanotechnology, biochemistry, and micro fluidics, the Lab-on-SkinTM sensing chip continuously collects ISF from the skin's surface and continuously analyzes its biochemical composition to detect changes in real time that indicate physiological state.

Website- https://xsensio.com/lab-on-skin-technology/

Xsensio

Health Care Originals: Intelligent Asthma Management

Website- https://www.healthcareoriginals.com/

IAM

Leaf Healthcare: Used in nursing home/hospital for tracking or preventing injuries

Website: https://www.sn-leaf.com/

Leaf

QardioCore: Track EKG, heart rate, body temperature and respiratory rate

Website- https://www.qardio.com/qardiocore-wearable

QardioCore

These are some examples of available wearables in elderly care. Probably there are more to this in today's market.

APPENDIX 2. The most relevant research articles selected

Author and Year	Article	Aim	Study type	Result
Baek, Jaeho 2023	Smart predictive analytics care monitoring model based on multi sensor IoT system: Management of diaper and attitude for the bedridden elderly.	Using smart wearables to study bedridden diaper status in elderly	Case study	The study shows that multi-sensor IoT call Diaper Care Device can detect urine, feces or fart in elderly.
Brannon, Grace, Ellen, Sophia, Mitchell & Liao, Yue 2022	Address privacy concerns for mobile and wearable devices sensors.	To find individuals' perceptions and acceptability of mobile and wearable sensors	Qualitative & thematic analysis	Study show elderly with health experiences such as cancer patients have more positive feeling towards wearables.
Dunn, Jessilyn, Runge, Ryan & Snyder, Michael 2018	Wearables and the medical revolution	The study reviews current and prospective wearable technologies and their progress toward a clinical application.	Case study	The study shows wearables will provide long term benefits.
Fang, Yu-Min & Chang, Chien-Cheng 2016	Users' psychological perception and perceived readability of	Investigated in terms of psychological perception and	Case study	Study shows wrist been most favourable to attach wearables

	wearable devices for elderly people	perceived readability.		
Fuller D, Colwell E, Low J, Orychock K, Tobin MA, Simango B, Buote R, Van Heerden D, Luan H, Cullen K, Slade L & Taylor NGA. 2020	Reliability and validity of commercially available wearable devices for measuring steps, energy expenditure, and heart rate.	To study the validity and reliability of commercial wearables.	Systematic Review	Study shows that commercial wearable devices have accurate measurement
Gaggi, Ombretta, Kolasinska, Agnieszka, Palazzi, Claudio & Quadrio, Giacomo 2020	Users Perception of Wearable Sensor Networks for Aging	The goal was to increase older folks' independence and safety.	A case study	The study shows that the majority of elderly are willing to adapt to proposed technology
Guk, Gaon, Han, Jaewoo, Lim, Keunwon, Jeong, Taejoon, Kang, Eun-Kyung, Lim & Juyeon, Jung 2019.	Real-Time Disease Monitoring for Personalized Healthcare	To summarizes of available wearable devices in today's market	Descriptive study	Wearable for elderly can reduce medical cost and contribute to population healthcare
Hale, Matthew L, Lotfy, Kerolos, Gamble, Rose F., Walter, Charles & Lin, Jessica 2018	Developing a platform to evaluate and assess the security of wearable devices	To find challenges and security treat with using wearable technologies	Comparative analysis	The study shows SecuWear help prevent several attacks and
Haghi, M., Thurow, K., & Stoll, R. 2017.	Wearable Devices in Medical Internet of Things.	To review wearable device benefits	Usability study method	Wearables long time use is reliable and beneficially for me health monitoring.

Huang, Pin-Chieh, Lin, Chung-Chih, Wang, Yu-Han & Hsieh, Hisang-Jen 2019	The development of Health Care System Based on Wearable Devices	To study the use of wearable device for elderly in Taiwan.	Case study	The study shows using a wearable device gives healthcare givers provides care services
Jose, Olmedo-Aguirre, Josimar, Reyes-Campos, Gina, Alor-Hernández, Machorro-Cano, I. Rodríguez-Mazahua & Sánchez-Cervantes 2022	Remote Healthcare for Elderly People Using Wearables.	Study devices, sensors, and wearables for measuring physiological parameters in elderly	Literature review	Study shows wearable device used in elderly care shows accurate measurement for clinical use.
Jo, Tae Hee, Jae Hoon Ma, and Seung Hyun Cha 2021	Elderly Perception on the Internet of Things-Based Integrated Smart-Home System	investigated in terms of perceived readability and psychological perception.	Empirical study design	The study shows that an elderly show willingness in wearables.
Kekade, Shwetambara, Hseieh, Chung-Ho, Islam, Mohaimenul, Atique, Suleman, Mohammed, Abdul-wahed, Khalfand, Yu-Chuan, Li, Shabbir & Syed Abdul 2018	Usefulness and actual use of wearable devices among the elderly population.	To evaluate the value of wearable technology for the elderly population	Literature review	Elderly was interested in the use of wearable device. Female user shows more willingness than their male counterpart
Kulurkar, Pravin, Dixit, Chandra kumar, Bharathi, V.C., Monikavishnuvarthini, A.,	AI based elderly fall prediction system using wearable sensors: A smart	The study reviews fall in elderly.	Case study	The study shows that wearables, sensors can detect or predict fall in elderly.

Dhakne, Amol & Preethi, P 2023.	home-care technology with IOT			
Li, He, Wu, Jing, Gao, Yiwen & Shi, Yao 2016	Examine individual adoption of healthcare wearable devices.	To find acceptance of wearable devices in healthcare	Literature review	Study shows adaptation of wearable device is based on privacy perception.
Marakhimov, Azizbek & Joo, Jaehun 2017	The consumer adaptation of wearable devices for healthcare, computers in human behaviour.	Behaviours using the post-adoption wearable healthcare gadgets	Case study	The study shows a sign of positive and negative impact on end users' health and privacy concerns.
McCallum Claire, Rooksby, John, Gray, Cindy M 2017.	Evaluating the Impact of Physical Activity Apps and Wearables	Aim is the evaluations of physical activity apps and wearables from acceptability and effectiveness point of view	Qualitative thematic analysis	The study shows that not all apps or wearables support physical activities.
Shieh, Meng-Dar, Hsiao, Hsu-Chan, Lin, Yi-Hsien, Lin & Jenn-Yang 2017	A study wearable device of the elderly people's perception	To study customer perception for the elderly.	Qualitative review	Different groups accept a different type of wearables
Sun, Fangmin, Zang, Weilin, Gravina, Raffaele, Fortino, Giancarlo, Li, Ye 2020	Gait-based identification for elderly users in wearable healthcare systems	To identify techniques that compare, improve access of wearable device in elderly.	Qualitative review	The study shows improve how elderly use wearable devices.

Stavropoulos, Thanos G., Asterios Papastergiou, Lampros Mpaltadoros, Spiros Nikolopoulos, and Ioannis Kompatsiaris. 2020.	IoT Wearable Sensors and Devices in Elderly Care.	The future of acceptable, practical, and effective eldercare through technology.	Literature Review	The study shows more usefulness in wearables
Talukderab, Shamim, Sorwarc, Golam, Bao, Yukun, Ahmed, Jashim Uddin, Palash, Abu Saeed 2020	Predicting antecedents of wearable healthcare technology ac-acceptance by elderly.	Wearable adoption by elderly or older population	Systematic literature review	The study shows that social influence and performance expectancy determine the adaptation of wearables in elderly
Qi, Wen, Zhou, Liang 2019	User-Centered Wearable Product Design for Community Elderly Care	advantages of using a wearable gadget to address such nursing issues with an elderly population.	Qualitative research	The study shows that using wearables significantly help and reduce caregiver time at long run
Qi, Wen, Zhou, Liang 2018	A User Study of Wearable Product for Elderly Care.	Wearable devices offer product designers a design methodology and parameters for their work.	Qualitative research	The study shows creating right product design for wearables encourage the use of wearables for aging population
Yap, Yee-Yann, Tan, Siow-Hooi, Choon, Shay-Wei 2022	Elderly's intention to use technologies	To identify different reasons on elderly technology adoption.	Systematic literature review	The result identifies 7 major antecedents' elderly adoption of wearables
Yu, Dengjie, Li, Zhe, Xie, Wenqing, Li,	Applications of nanogenerator-	They study reviews how	Case study	The study suggests further

Daishi, Li, Zhou, Li, Yusheng 2022	based wearable devices in ortho-paedics.	wearable device can be used in orthopaedics.		investigation of NG-based weara-bles