REVIEW

Biosensor applications in the monitoring of elderly patients

Busra Kul [1]

[1] Uskudar University, Vocational School of Health Services, Uskudar, 34664, **Istanbul, Türkiye**
ROR ID: 02dzjmc73
* **Corresponding author**: E-mail: busra.kul@uskudar.edu.tr; Ph.: +90-216-400-2222; Fax: +90-216-474-1256.

Citation: Kul, B., (2025). Biosensor applications in the monitoring elderly patient. Euchembioj Rev. 1, 35-44. https://doi.org/10.62063/rev-12

Peer review: Externally peer reviewed.

Received: 13.06.2024
Accepted: 09.09.2024
Online first: 15.10.2024
Published: 25.01.2025

Abstract

Nurse-based patient monitoring is prone to errors due to manual measurements and documentation, leading to potential inaccuracies in care. The use of biosensors offers a promising solution by enabling real-time and continuous monitoring of patient health. Categorizing patient care reports as critical or non-critical using mobile recording systems based on biosensor data can help prevent errors and improve care. The use of biosensors can significantly reduce morbidity and mortality, especially after emergencies and accidents. These devices improve the quality of care and increase the satisfaction of older people, their families and healthcare professionals. Wearable biosensors make it easier for older people to monitor their health, which can help reduce hospital admissions. Chronic diseases such as cardiovascular disease, cancer, diabetes, dementia and stroke pose challenges to healthcare delivery and interpretation of results. Integrating biosensors into health monitoring and measurement is an innovative approach to managing these chronic conditions more effectively. To improve self-management of chronic diseases in older people, it is essential to educate healthcare professionals and promote research in this area. As a result, the use of biosensors to monitor the daily activities and health parameters of elderly patients is expanding, highlighting the importance of multidisciplinary research in biotechnology, chemistry, engineering and nursing.

Keywords: Biosensor, geriatrics, wearable biosensor, nursing; innovative approaches

Introduction

The increasing elderly population in recent years has caused some problems to arise. The growth of health expenditures of the elderly struggling with aging and chronic diseases requires the adoption of effective measures worldwide. Traditional health monitoring methods often involve periodic assessments and manual documentation, which can be prone to delays and inaccuracies, but biosensors overcome these limitations by offering the potential for continuous and real-time monitoring (Kalid et al., 2018; Ledikwe et al., 2014). However, they have their own challenges, including issues related to battery life, user comfort and data security (Pateraki et al., 2020). Biotechnology has begun to be used to monitor these problems and to enable the elderly to live healthily in a comfortable, reliable environment. It is very important to develop and use biotechnology systems in daily life so that the elderly can continue their daily life activities and detect emergencies or accidents such as stroke, fall, syncope and myocardial infarction (Lin et al., 2007; Olmedo-Aguirre et al., 2022). Using biotechnology, chronic diseases can be prevented and adequately monitored, and health risks can be identified to improve the quality of life of the elderly (Olmedo-Aguirre et al., 2022).

The elderly population is expected to be 2.1 billion in 2050 (Keating, 2022). The increase in the elderly population increases the incidence of chronic diseases such as cardiovascular diseases, cancer, dementia and diabetes. In a study, it was found that 78.7% of the elderly had chronic diseases and the rate of those who stated that these diseases seriously limited the patient's daily life activities was 32.3%. It has been observed that 24% of the elderly have fallen inside or outside the home in the last year. 54.6% of the elderly stated that they would like to benefit from home care services in the future, and 41.3% stated that they would prefer a nursing home (TÜİK, 2023). In the world, the incidence of death due to cardiovascular diseases is 32%, the incidence of death due to cancer is 16.8% and the incidence of death due to diabetes is 2.5%. There are 422 million diabetics and more than 55 million dementia patients in the world (Hacker, 2024). It is imperative to monitor the health status of people who have these diseases and are at risk of contracting these diseases. Since sufficient time, attention, discipline and knowledge are required to monitor the patient's physiological changes, the use of biosensor technology in monitoring the changes occurring in the patient is extremely important. In the studies, patients' balance status changes, falls during work, physical activity and vital signs were monitored. In these studies, elderly people with cardiovascular disease, respiratory diseases, sleep problems, diabetes, osteoporosis, Parkinson's disease, alcohol addiction and seizures were followed (Olmedo-Aguirre et al., 2022).

Biosensors enable our body to communicate and react better with our environment, diagnose diseases early, and improve health by detecting diseases early. The body's physiological response transmits data to the control unit through wearable biosensors, the control unit analyzes the data, and health parameters are transmitted to the mobile device (Smith et al., 2023). Appropriate selection of biomarkers indicating health and disease states is vital for the diagnosis and treatment of the disease by detecting it before it occurs (Salek-Maghsoudi et al., 2018).

In intensive care, patients whose physiological parameters are monitored with a bedside monitor and alarm system can be monitored at any place and time using a lightweight, wearable, and wireless biosensor because of current developments. The biosensor processes digital data and transmits the necessary data to communicate. Transmission distance, frequency, and battery life are the most important problems in the application. In nursing homes, the elderly person carries a tiny biosensor. If he falls in an area such as a park or a toilet, it becomes easier for the nurse to detect the elderly

person's condition early and find his location through a call containing information to the base station. To extend the battery life of the biosensor, it is recommended that it be turned on only for measurement and not monitored continuously. However, it is extremely important to have the sensors turned on in places where the elderly are alone, such as parks, neighborhoods, gardens, and toilets, to constantly monitor the elderly's vital signs such as temperature, pulse rate and number, respiratory rate, saturation, and heart rhythm, and to take immediate action for help by monitoring their location. In addition, the necessary health care can be provided because the parameters that the elderly follow themselves, such as blood pressure and blood sugar, can be monitored (Lin et al., 2007).

Through this system, we can track and record the elderly person's time to get up, go to the restroom, exercise, go to a restaurant, and perform daily living activities. We can follow the social life of the elderly and provide psychosocial support by detecting abnormal mental states at an early stage (Lin et al., 2007). Elderly people with chronic diseases can adjust their diets and daily routines in time according to system data and save money economically by reducing hospitalizations. It can enable patients to understand their health status in real time and ensure timely hospitalization (Smith et al., 2023).

Tracking physiological variables

With the development of technology, biosensors have been developed that can monitor the physiological variables seen in all chronic diseases. Heart rate and number, pulse rate and number, respiratory rate and number, blood oxygen saturation (SpO_2), blood pressure, and blood sugar of elderly people suffering from chronic diseases can be monitored through biosensors (Miller et al., 2021; Olmedo-Aguirre et al., 2022; Wang et al., 2017). Respiratory rate and rate can be used to detect, diagnose, and monitor patients affected by chronic diseases such as anxiety, pneumonia, heart failure, lung disease, and drug coma. In addition to smartwatches, intradermal sensors, portable sensors, rings, and insoles are used to monitor these variables. While it is easier to design sensors that can read parameters such as blood oxygen level and heart rate for monitoring cardiovascular diseases, device placement and maintenance becomes difficult because sensors must be implanted at the bone level for osteoporosis, which requires constant monitoring of the patient's bones. The size of the sensors used, the methods of placing the sensors on the human body, and their subsequent removal cause some difficulties. For these reasons, very few biosensors are still available for many chronic degenerative diseases such as osteoporosis, some types of cancer, and gastrointestinal diseases (Olmedo-Aguirre et al., 2022; Wang et al., 2017).

Blood glucose monitoring: Noninvasive intravascular blood glucose can be measured with ultra-thin skin-like biosensors on a flexible biocompatible paper battery. The battery connects to the skin and creates electrochemical channels in the subcutaneous tissue (Chen et al., 2017). Continuous blood sugar monitoring can be done using a contact lens with a photonic glucose sensor and smartphone camera reading (Elsherif et al., 2018). Electromagnetism sensors are a noninvasive, permanent, portable, patch-shaped system that mimics vascular anatomy. It is suitable for personalized monitoring according to the patient's characteristics (Hanna et al., 2020). It is also used in disposable patch-type devices that measure glucose levels in sweat and automatically apply the drug via a transdermal drug delivery device (Lee et al., 2017).

Pulse rate and respiration rate: Smart bracelets, watches, belts and armbands can be used to monitor health status and give timely warnings, displaying parameters such as pulse rate, electrocardiogram (ECG) and respiratory rate. Respiration rate is estimated from an arm-worn cuff ECG

using a method based on changes in QRS slopes and the angle of the R wave. Predictions are compared with those obtained from the respiratory signal. The cuff contains a pair of dry electrodes that record the ECG and is designed for long-term monitoring (Lázaro et al., 2018). With IoT-based wearable devices, pulse rate and ECG findings can be transmitted to the computer or mobile phone and the data can be monitored continuously (Sani et al., 2019; Xiao et al., 2020). The leg belt is a portable ECG sensor system that captures the patient's vital data through the skin by detecting signals with patch electrodes. This system can collect 6 ECG signals (Hussein et al., 2017). In a study conducted with emergency room patients, it was observed that the respiratory rate measured using the Philips wearable biosensor was detected continuously and accurately without intervention. The fact that the Philips wearable sensor is a lightweight, wireless, battery-powered device and sticks to the skin makes it easier to use. It is attached to the patient's chest, allowing the patient's respiratory rate, pulse rate, gait and posture to be monitored (Li et al., 2019). Heart rate increases acutely with exertion and stress and decreases rapidly during relaxation and sleep. Heart rate is used to evaluate sleep quality. In addition, the slow decrease in the heart rate of dementia and Parkinson's disease over months allows the disease to be recognized in its early stages. Respiratory rate increases due to decompensation of stress, fever and lung diseases, and pulmonary edema in heart failure (Saner, 2018).

Blood pressure: Optical-based heart rate sensors can be attached to wristwatches, earbuds, behind-the-ears, and glasses. To measure blood pressure, the wristwatch is brought close to the chest and the micro-vibrations of the heartbeat in the chest are detected. As the pulse wave moves from the heart to the wrist, measurements are made by an optical sensor and an accelerometer in the watch (Carek et al., 2017). With the illuminated pulse sensor connected to an inflatable tube placed inside the ear, blood pressure measurements can be made easily during the daily activities of the elderly, maximizing the comfort level (Bui et al., 2019).

In a study conducted in the emergency department, continuous monitoring of vital signs with wearable biosensors enabled the detection of potential clinical problems 5.5 hours earlier compared to standard monitoring (Garbern et al., 2019). In a study conducted in a general ward, it was found that measurements made with wearable sensors gave up to 10 hours warnings earlier (Weenk et al., 2019).

The monitoring of balance disorders

Moderate or severe injuries occur in 30% of elderly people because of falls. In this case, it may cause disability in the elderly, restriction of physical activity, and earlier admission to a nursing home. For the elderly to maintain their independence and mobility, it is very important to determine the factors affecting postural stability and design special interventions. Balance control is a complex skill based on the interaction of sensorimotor processes. Accelerometers are used to evaluate the balance status of the elderly. Accelerometers are economical, mobile and lightweight inertial sensors used to perform post-urography. In case of imbalance, the rod on the accelerometer deflects and the springs detect their acceleration. Accelerometers monitor physical activity, that is, measure the duration of endurance in different activities, such as intense exercise or rest (sitting, lying). This device can encourage the elderly to do physical activity. The accelerometer can be carried by attaching to the elderly person's body, arm or any desired area with a fixed belt and can measure the elderly person's daily life activities (Leirós-Rodríguez et al., 2019). Studies have shown that placing more than one sensor on the patient is more reliable. It has been determined that if a single sensor is to be placed on the elderly, it should be

placed on the waist, chest, head or pelvis instead of the ankle. Since the asymmetry in foot movements prevents the sensor from detecting the situation after the fall begins, it must be monitored by installing at least two sensors (Aziz et al., 2014; Howcroft et al., 2016). Additionally, the patient's data is transmitted to the mobile device via wearable sensors. If the patient falls, this system sends a message to the emergency room, family members or caregivers for timely intervention (Smith et al., 2023). Apart from this, the activity of the elderly can be detected, and risks can be evaluated by monitoring environmental conditions with environmental biosensors (Sun et al., 2022).

The monitoring of pressure sore

Pressure sore is a condition that can occur frequently in elderly patients. Approximately 9% of hospitalized patients develop pressure sores. As a result of impaired blood flow in areas exposed to constant pressure, tissue necrose and a pressure sore occur. To detect the onset of a pressure sore early, the electrochemical enzyme-based biosensor is attached to the patient's body and allows continuous and noninvasive monitoring of the lactate level in sweat. It is thought that pressure sores can be prevented by monitoring them with alarming biosensors. Studies have found that lactate level is directly related to pressure sore development (Tur García, 2014). Additionally, wound management is expensive as it requires several days of testing and reduces the patient's quality of life. Therefore, uric acid biosensors in the form of adhesive tape have been developed to prevent complications and to detect the progress of the wound in time. Uric acid concentration indicates the healing process in the wound area. The high uric acid concentration in chronic wounds decreases with treatment, and the healing process can be monitored by constantly measuring uric acid levels in the wound area. Apart from this, a biosensor that measures pH can also be used in wound monitoring. As the wound heals and the tissue regenerates, the pH of the skin passes from alkaline to acidic, in which case pH monitoring can be done for wound care (Arakawa et al., 2022).

Incontinent patient monitoring

Since it is difficult to collect the urine of elderly people who have urinary incontinence problems, it is important to use an economical and useful biosensor. In a study, a multi-parameter biosensor was placed on the diaper to detect urine biomarkers, and the nurse was able to monitor when the diaper needed to be changed by detecting it with detection systems. By placing a multi-parameter electrochemical biosensor in an ordinary cloth, on-site detection of glucose and uric acid in urine was achieved. With this sensor, doctors can access urine biomarker data to assess the health status of their patients. In this way, it can better monitor the elderly living in nursing homes. It is thought that thanks to the biosensor placed in the patient's diaper, patients will avoid embarrassment, and patients with incontinence will live with more dignity (Su et al., 2022).

Infection tracking

Microorganisms are not visible to the naked eye, but they are found everywhere and are the main causes of diseases. Microorganisms can be detected through biosensors. Some infectious diseases have no cure and are very dangerous. Therefore, preventing diseases by determining these infection biomarkers with biosensors can reduce the economic burden and deaths. Biosensors are used to detect many pathogens such as human papillomavirus, hepatitis B virus, mycobacterium tuberculosis, meningitis, toxoplasma gondii, and leprosy (Chatterjee et al., 2022).

Behavior tracking

Behavioral detection is a more objective approach than neuropsychiatric scales used to detect Alzheimer's disease at an early stage. It is safer and more comfortable than invasive methods. It is also more economical than neuroimaging tests. With the development of technology, behavioral detection biosensors such as motion sensors and sound sensors have begun to be used to measure various behavioral biomarkers of the elderly. Behavioral sensing sensors are used in society for entertainment, comfort, natural interaction, assisted living, security, etc. It attracts more attention because it supports many areas such as. For example, the problem of aging increases the demand for home healthcare services for the elderly. The continued use of behavior monitoring biosensors is urgently needed to ensure that elderly people, especially those living alone, live in a safer environment and to detect abnormal behavior. Additionally, behavioral detection biosensors can be used to detect Parkinson's disease, stroke, etc. Behavioral disorders of diseases are also determined. Behavioral biomarkers may be vital indicators in the early stages of Alzheimer's disease. In patients, symptoms such as changes in motor behavior occur before profound memory deficits. Therefore, since motor behavior changes usually occur with old age, behavioral detection biosensors are vital for both the early diagnosis of Alzheimer's disease and the ability of the elderly to perform daily living activities. With behavioral detection biosensors, body movement behavior, eye movement behavior, multimodal behavior, speech and language behavior applications are detected. Multimodal behavioral sensors enable the examination of multiple behavioral parameters such as physiological indicators, eye movement, voice and body movements, along with environmental factors. Body movement behavior sensors can detect walking speed, walking stride, balance, foot kicking, upper limb movement, and other activities in daily living. Eye movement behavior sensors are used to measure looking, blinking, fixation, saccades, and pupillary response. Speech and language behavior sensors serve to identify and record acoustic features. Among the biosensors used to detect behavior in the diagnosis of Alzheimer's disease, multimodal behavioral sensors are the method that best distinguishes normal and abnormal behaviors (Sun et al., 2022).

In a hospital or nursing home, nurse-based patient monitoring is prone to errors due to manual measurement and documentation. Therefore, categorizing patient care reports as critical or non-critical reports with mobile recording using network systems according to biosensor values can prevent problems. Important clinical parameters, such as heart rate, may be subject to measurement error and subsequently lead to inaccurate results in nursing care. Patient status alarms created using automation systems are triggered in abnormal situations that occur in the patient and can provide warnings at different levels depending on the severity of the situation. It also provides 24-hour support to the elderly, patients, and caregivers (Vithya & Vinayaga Sundaram, 2017).

With the use of biosensors, morbidity and mortality can be reduced after emergencies and accidents. The quality-of-care increases and the satisfaction of the elderly/family and the nurse increases (Lin et al., 2007). Chronic diseases such as cardiovascular diseases, cancer, diabetes, dementia and stroke make the delivery of health care and the interpretation of results difficult. The use of biosensors in health measurements and patient monitoring are innovative approaches to reduce the burden of chronic diseases. Informing healthcare professionals and conducting encouraging research on this issue is extremely important for the self-management of chronic diseases in elderly patients. However, biotechnology applications are costly, applications in the field of health are limited and difficult to access (Hacker, 2024). Advanced technologies are not accepted by the elderly, and they experience difficulties because they do not have the necessary skills to use them (Olmedo-Aguirre

et al., 2022).

Conclusions

Biosensors offer significant advantages in monitoring the health of elderly patients by providing continuous data and enabling early detection of health issues. They are instrumental in real-time monitoring and intervention, potentially revolutionizing the management of chronic conditions and enhancing overall care. Various types of biosensors are currently under research worldwide, demonstrating their utility in diagnosing autoimmune diseases, cancer, neurodegenerative diseases, and cardiovascular conditions. While these advancements hold promise for improving early diagnosis and preventative care, challenges such as limited battery life, user discomfort, and concerns regarding data security and privacy remain. Ongoing research and technological improvements are essential to overcome these hurdles and fully realize the potential of biosensors. As the field progresses, biosensors are expected to play a crucial role in advancing healthcare and providing more effective and personalized care for elderly patients.

Acknowledgements

None.

Funding

None.

Conflict of interest

The authors declare no conflict of interest.

Data availability statement

Data sharing is not applicable to this review article as no datasets were generated or analyzed during the current study.

Ethics committee approval

Ethics committee approval is not required for this study.

Authors' contribution statement

Study conception and design: BK; **Data collection**: BK; **Manuscript draft preparation**: BK All authors reviewed the results and approved the final version of the manuscript.

ORCIDs and emails of the authors

Busra Kul | ORCID 0000-0002-8196-229X | busra.kul@uskudar.edu.tr

References

Arakawa, T., Dao, D. V., & Mitsubayashi, K. (2022). Biosensors and chemical sensors for healthcare monitoring: a review. *IEEJ Transactions on Electrical and Electronic Engineering, 17*(5), 626-636. https://doi.org/10.1002/tee.23580

Aziz, O., Park, E. J., Mori, G., & Robinovitch, S. N. (2014). Distinguishing the causes of falls in hu-

mans using an array of wearable tri-axial accelerometers. *Gait & posture*, 39(1), 506-512. https://doi.org/10.1016/j.gaitpost.2013.08.034

Bui, N., Pham, N., Barnitz, J. J., Zou, Z., Nguyen, P., Truong, H., Kim, T., Farrow, N., Nguyen, A., & Xiao, J. (2019). ebp: A wearable system for frequent and comfortable blood pressure monitoring from user's ear. The 25th annual international conference on mobile computing and networking. https://doi.org/10.1145/3300061.3345454

Carek, A. M., Conant, J., Joshi, A., Kang, H., & Inan, O. T. (2017). SeismoWatch: wearable cuffless blood pressure monitoring using pulse transit time. *Proceedings of the ACM on interactive, mobile, wearable and ubiquitous technologies, 1*(3), 1-16. https://doi.org/10.1145/3130905

Chatterjee, N., Manna, K., Mukherjee, N., & Saha, K. D. (2022). Challenges and future prospects and commercial viability of biosensor-based devices for disease diagnosis. *Biosensor Based Advanced Cancer Diagnostics*, 333-352. https://doi.org/10.1016/B978-0-12-823424-2.00013-2

Chen, Y., Lu, S., Zhang, S., Li, Y., Qu, Z., Chen, Y., Lu, B., Wang, X., & Feng, X. (2017). Skin-like biosensor system via electrochemical channels for noninvasive blood glucose monitoring. *Science advances*, 3(12), e1701629. https://doi.org/10.1126/sciadv.1701629

Elsherif, M., Hassan, M. U., Yetisen, A. K., & Butt, H. (2018). Wearable contact lens biosensors for continuous glucose monitoring using smartphones. *ACS nano, 12*(6), 5452-5462. https://doi.org/10.1021/acsnano.8b00829

Garbern, S. C., Mbanjumucyo, G., Umuhoza, C., Sharma, V. K., Mackey, J., Tang, O., Martin, K. D., Twagirumukiza, F. R., Rosman, S. L., & McCall, N. (2019). Validation of a wearable biosensor device for vital sign monitoring in septic emergency department patients in Rwanda. *Digital health, 5*, 2055207619879349. https://doi.org/10.1177/2055207619879349

Hacker, K. (2024). The burden of chronic disease. *Mayo Clinic Proceedings: Innovations, Quality & Outcomes, 8*(1), 112-119. https://doi.org/10.1016/j.mayocpiqo.2023.08.005

Hanna, J., Bteich, M., Tawk, Y., Ramadan, A. H., Dia, B., Asadallah, F. A., Eid, A., Kanj, R., Costantine, J., & Eid, A. A. (2020). Noninvasive, wearable, and tunable electromagnetic multisensing system for continuous glucose monitoring, mimicking vasculature anatomy. *Science advances, 6*(24), eaba5320. https://doi.org/10.1126/sciadv.aba5320

Howcroft, J., Lemaire, E. D., & Kofman, J. (2016). Wearable-sensor-based classification models of faller status in older adults. *PLoS one, 11*(4), e0153240. https://doi.org/10.1371/journal.pone.0153240

Hussein, A. F., Hashim, S. J., Aziz, A. F. A., Rokhani, F. Z., & Adnan, W. A. W. (2017). A real time ECG data compression scheme for enhanced bluetooth low energy ECG system power consumption. *Journal of Ambient Intelligence and Humanized Computing*, 1-14. https://doi.org/10.1007/s12652-017-0560-y

Kalid, N., Zaidan, A., Zaidan, B., Salman, O. H., Hashim, M., & Muzammil, H. (2018). Based real time remote health monitoring systems: A review on patients prioritization and related" big data" using body sensors information and communication technology. *Journal of medical systems, 42*, 1-30. https://doi.org/10.1007/s10916-017-0883-4

Keating, N. (2022). A research framework for the United Nations Decade of Healthy Ageing (2021–

2030). *European Journal of Ageing, 19*(3), 775-787. https://doi.org/10.1007/s10433-021-00679-7

Lázaro, J., Bailón, R., Gil, E., Noh, Y., Laguna, P., & Chon, K. H. (2018). Pilot study on electrocardiogram derived respiratory rate using a wearable armband. Computing in Cardiology Conference (CinC). https://doi.org/10.22489/CinC.2018.054

Ledikwe, J. H., Grignon, J., Lebelonyane, R., Ludick, S., Matshediso, E., Sento, B. W., Sharma, A., & Semo, B.-w. (2014). Improving the quality of health information: a qualitative assessment of data management and reporting systems in Botswana. *Health research policy and systems, 12*, 1-10. https://doi.org/10.1186/1478-4505-12-7

Lee, H., Song, C., Hong, Y. S., Kim, M., Cho, H. R., Kang, T., Shin, K., Choi, S. H., Hyeon, T., & Kim, D.-H. (2017). Wearable/disposable sweat-based glucose monitoring device with multistage transdermal drug delivery module. *Science advances, 3*(3), e1601314. https://doi.org/10.1126/sciadv.1601314

Leirós-Rodríguez, R., García-Soidán, J. L., & Romo-Pérez, V. (2019). Analyzing the use of accelerometers as a method of early diagnosis of alterations in balance in elderly people: A systematic review. *Sensors, 19*(18), 3883. https://doi.org/10.3390/s19183883

Li, T., Divatia, S., McKittrick, J., Moss, J., Hijnen, N. M., & Becker, L. B. (2019). A pilot study of respiratory rate derived from a wearable biosensor compared with capnography in emergency department patients. *Open Access Emergency Medicine*, 103-108. https://doi.org/0.2147/OAEM.S198842

Lin, Y.-J., Su, M.-J., Chen, S.-J., Wang, S.-C., Lin, C.-I., & Chen, H.-S. (2007). A study of ubiquitous monitor with RFID in an elderly nursing home. International Conference on Multimedia and Ubiquitous Engineering (MUE'07). https://doi.org/10.1109/MUE.2007.55

Miller, K., Baugh, C. W., Chai, P. R., Hasdianda, M. A., Divatia, S., Jambaulikar, G. D., & Boyer, E. W. (2021). Deployment of a wearable biosensor system in the emergency department: a technical feasibility study. Proceedings of the... Annual Hawaii International Conference on System Sciences. Annual Hawaii International Conference on System Sciences. https://doi.org/10.24251/HICSS.2021.433

Olmedo-Aguirre, J. O., Reyes-Campos, J., Alor-Hernandez, G., Machorro-Cano, I., Rodriguez-Mazahua, L., & Sanchez-Cervantes, J. L. (2022). Remote healthcare for elderly people using wearables: A review. *Biosensors, 12*(2), 73. https://doi.org/10.3390/bios12020073

Pateraki, M., Fysarakis, K., Sakkalis, V., Spanoudakis, G., Varlamis, I., Maniadakis, M., Lourakis, M., Ioannidis, S., Cummins, N., & Schuller, B. (2020). Biosensors and Internet of Things in smart healthcare applications: Challenges and opportunities. *Wearable and Implantable Medical Devices*, 25-53. https://doi.org/10.1016/B978-0-12-815369-7.00002-1

Salek-Maghsoudi, A., Vakhshiteh, F., Torabi, R., Hassani, S., Ganjali, M. R., Norouzi, P., Hosseini, M., & Abdollahi, M. (2018). Recent advances in biosensor technology in assessment of early diabetes biomarkers. *Biosensors and Bioelectronics, 99*, 122-135. https://doi.org/10.1016/j.bios.2017.07.047

Saner, H. (2018). Wearable sensors for assisted living in elderly people. *Frontiers in ICT, 5,* 1. https://doi.org/10.3389/fict.2018.00001

Sani, M. I., Mutiara, G. A., & Putra, R. S. D. W. (2019). Fit-NES: Wearable bracelet for heart rate monitoring. *TELKOMNIKA (Telecommunication Computing Electronics and Control), 17*(1), 392-399. https://doi.org/10.12928/telkomnika.v17i1.11611

Smith, A. A., Li, R., & Tse, Z. T. H. (2023). Reshaping healthcare with wearable biosensors. *Scientific Reports, 13*(1), 4998. https://doi.org/10.1038/s41598-022-26951-z

Su, H., Sun, F., Lu, Z., Zhang, J., Zhang, W., & Liu, J. (2022). A wearable sensing system based on smartphone and diaper to detect urine in-situ for patients with urinary incontinence. *Sensors and Actuators B: Chemical, 357*, 131459. https://doi.org/10.1016/j.snb.2022.131459

Sun, X., Sun, X., Wang, Q., Wang, X., Feng, L., Yang, Y., Jing, Y., Yang, C., & Zhang, S. (2022). Biosensors toward behavior detection in diagnosis of alzheimer's disease. *Frontiers in Bioengineering and Biotechnology, 10*, 1031833. https://doi.org/10.3389/fbioe.2022.1031833

TÜİK. Türkiye Yaşlı Profili Araştırması, 2023. Retrieved June, 27 from https://data.tuik.gov.tr/Bulten/Index?p=Turkiye-Yasli-Profili-Arastirmasi-2023-53809.

Tur García, E. (2014). Development of a flexible biosensor for the monitoring of lactate in human sweat for its medical use in pressure ischemia. Cranfield University, UK.

Vithya, G., & Vinayaga Sundaram, B. (2017). Inpatient critical stage monitoring in smart hospitals by contextual Fuzzy based QoS routing for WBMS network nurse call system. *Wireless Personal Communications, 94*, 2065-2080. https://doi.org/10.1007/s11277-016-3361-2

Wang, Z., Yang, Z., & Dong, T. (2017). A review of wearable technologies for elderly care that can accurately track indoor position, recognize physical activities and monitor vital signs in real time. *Sensors, 17*(2), 341. https://doi.org/10.3390/s17020341

Weenk, M., Koeneman, M., van de Belt, T. H., Engelen, L. J., van Goor, H., & Bredie, S. J. (2019). Wireless and continuous monitoring of vital signs in patients at the general ward. *Resuscitation, 136*, 47-53. https://doi.org/10.1016/j.resuscitation.2019.01.017

Xiao, N., Yu, W., & Han, X. (2020). Wearable heart rate monitoring intelligent sports bracelet based on Internet of things. *Measurement, 164*, 108102. https://doi.org/10.1016/j.measurement.2020.108102