eHEALTH WEARABLES DETECTING COGNITIVE IMPAIRMENT: META-ANALYSIS

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Abstract: *eHealth wearables offer significant value in the detection and monitoring of cognitive impairment by shifting from episodic clinical check-ups to continuous, passive, real-world tracking.*

This paper presents a brief review and meta-analysis of eHealth wearables application for the detection of cognitive impairments.

ЕЛЕКТРОННО ЗДРАВЕОПАЗВАНЕ: НОСЕНИ ВЪРХУ ТЯЛОТО УСТРОЙСТВА ЗА ОТКРИВАНЕ НА КОГНИТИВНИ НАРУШЕНИЯ: МЕТА АНАЛИЗ

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Ключови думи: *Електронно здравеопазване, устройства, носени на тялото, когнитивни нарушения*

Резюме: *Носените върху тялото електронни устройства могат да са от изключителна полза при откриването и проследяването на когнитивни нарушения. Те са в състояние да променят подхода от епизодични клинични прегледи към непрекъснато наблюдение в реална среда.*

В настоящата статия са представени кратък обзор и мета-анализ на приложението на подобни устройства за регистрирането на когнитивни нарушения.

Introduction

eHealth wearables

eHealth wearables are electronic devices worn on the body. Well-known examples of eHealth wearables are smartwatches, rings, patches and smart textiles. The purpose of wearing them is the continuous track of vital signs to support building a healthy lifestyle, remote patient monitoring, chronic disease management and preventive healthcare.

The most common types of wearable devices used to enhance subjects / patients' outcomes and well-being are:

- Smartwatches and fitness trackers monitoring heart rate, activity levels, sleep patterns;
- Continuous glucose monitors that track blood sugar levels in real time for diabetics;
- Wearable Electrocardiogram (ECG) and blood pressure monitoring devices;
- Wearable sleep trackers;
- Smart clothing and biosensors tracking muscle activity, posture, movements;
- Wearable neuro devices monitoring brain activity;
- Fall detection devices and
- Wearable respiratory monitors.

Wearable health technology market, including smart clothing, is forecast at $175 billion in 2026, on track toward $383.5 billion by 2032. Medical smartwatches and the clinical wearable market are the fastest-growing segment of wearable tech market, expanding at roughly 25% annually.

eHealth wearables may offer significant value in the detection and monitoring of cognitive impairment by shifting from episodic clinical check-ups to continuous, passive, real-world tracking.

Cognitive impairment

Cognitive impairment is an inclusive term describing any characteristic that acts as a barrier to the cognition process or different areas of cognition.

Key facts characterizing cognitive impairment are:

- Problems remembering things, problems with concentration and/or making decisions and solving problems;
- Changes in behavior, difficulty controlling emotions and trouble communicating with others.

Cognitive impairment is not an illness but it can be a sign for other health conditions. Roughly, cognitive impairment has three level of severity:

- Mild cognitive impairment, i.e. minor changes in memory or thinking that are noticeable, but do not stop a person from living independently;
- Major Neurocognitive Disorder (Dementia), i.e. severe decline in multiple cognitive areas that interferes with daily tasks and independence and
- Delirium – a sudden, short-lived change in attention and consciousness that often fluctuates throughout the day.

Causes of cognitive impairment include dementia, depression, delirium, head injury or stroke.

According to WHO, primary risk factors for development of cognitive impairments are advancing age; lower educational attainment; depression status and psychological distress; vascular and cardiovascular conditions (such as high blood pressure and history of stroke), low physical activity and low socioeconomic status.

The global prevalence of mild cognitive impairment (MCI) among older adults is estimated at 23.7% according to recent meta-analyses, though rates vary from roughly 12% to over 25% depending on age, region, and whether individuals live in community or institutional settings. Approximately 10% to 15% of people with MCI progress to a dementia diagnosis each year, with about one-third developing Alzheimer's-related dementia within five years. According to WHO, the number of people with dementia is set to triple by 2050 world-wide.

eHealth Wearables Detecting Cognitive Impairment

Early detection is critical for slowing the decline of cognitive function and lowering the risk of dementia.

Current methods to monitor cognitive decline involve being assessed at a doctor’s office. Such evaluations are very helpful but they can only capture a moment in time and, depending on the socio-economic status of the individual, may not be regularly available.

As wearable technology becomes more widespread, it has become a useful tool for tracking various health statistics that could help pick up on deviation or decline in an individual’s typical performance.

Applying eHealth wearables, early and mild cognitive impairments are studied by tracking digital biomarkers such as heart rate, EEG, sleep cycles, physical activity during everyday life and match the results with lifestyle factors (stress, diet, exercise …) in reality.

The Goal

The goal of this paper is to present, in brief, the results from a review and meta-analysis trying to identify if there is an effect of application of eHealth wearables for detection of mild cognitive impairment.

Method

A systematic search was performed to identify the relevant studies.

The following databases were used: APA PsychNet, PubMed, IEEE and Google Scholar. These databases were selected as:

APA PsychNet is the world's largest resource devoted to peer-reviewed literature in behavioral science and mental health.

PubMed contains more than 40 million citations and abstracts of biomedical and life sciences literature dating back to 1946. As it does not always provides direct full-text articles, though it often includes links to free or subscriber-based full-text versions on publisher sites, Google Scholar database is used as a source for free online full text articles, if and when available.

IEEE focuses on electrical engineering, electronics, computer science, telecommunications, artificial intelligence, and allied technological fields thus, eHealth wearables applications are also included in it.

The search period was from January 1st, 2022 – October 1st, 2026.

To make the selection as broad as possible and not to miss any publications, the key words were “eHealth wearable/s” “Cognitive impairment/s”.

Included criteria were:

- The research is focused on both “eHealth wearable/s” “Cognitive impairment/s”;
- The research is published in a journal and for the first time;
- The paper is a systematic review;
- The research is published in English;
- The subjects / patients are adults;
- The research introduces or discussed “eHealth wearable/s” related to “Cognitive impairment/s”;
- The research is an original one and the full text is available in one or another database.

Studies that did not meet one or more of the above criteria were excluded from the review.

Microsoft Excel template was created, helping to extract the information needed for the analysis: list of authors, country of research, methodology used; information about subjects included in the study (age, gender, ethnicity), description of findings, impact statements.

To synthesize and describe the data, the narrative approach was applied.

Results and Discussion

The first step of the selection was to extract all systematic reviews that were available in “full text” and include “eHealth wearable/s” related to “Cognitive impairment/s”; anywhere in the text, excluding the references.

45 papers were identified.

The next step was to add, “first posting” to exclude papers that were updated versions of studies performed before. In addition, a checking to evaluate whether the index terms are both “eHealth wearable/s” related to “Cognitive impairment/s” was performed. The index terms are the terms that captures the essence of the topic of a document. All articles that do not meet these criteria were rejected.

Titles and abstracts, then full text screening were carried out to assess the article eligibility against the inclusion criteria. Any arising disagreements were resolved by discussion.

Three more papers were excluded as the focus was on AI and machine learning. From original 45 publications only 15 were included in the analysis [1–15].

Due to the limited space of the paper, a summary of the results is presented.

Description of Included Studies

The included studies were published from 12 countries most of them European (Greece, Denmark, France, Italy, Luxembourg, UK, Spain, Saudi Arabia, Canada, USA, India, China).

Recruited participants vary from 5 up to 3019.

Ethnicity and/or the cultural background of participants were not reported in all studies. Most of the participants were identified as white.

Wide range of methods to monitor cognitive and physiological functions are used:

- Movement and gait devices follow and record walking speed, balance, dual-task performance, etc. [1, 3, 6, 7, 11].
- Sleep pattern and circadian rhythm are studied in [1, 5, 8, 10, 13].
- Brain activity, i.e. electroencephalogram (EEG), is documented via wireless sensors during task execution or daily activities [5, 12, 14];
- Speech analysis tools use specialized acoustic, inertial, and physiological sensors to track, decode, or analyze vocal patterns, vocabulary richness, pronunciation, throat vibrations, etc [11].
- Blood pressure [4], posture sensors [13] and home monitoring devices [9] are also used.

Results

Before summarizing the results, it is necessary to underline that most of the studies come from high-income Western countries, i.e. some of the results may not be exactly applicable to low-income communities. This is essential, as the socioeconomic status is one of the preliminary risks of development of cognitive impairments. Low socioeconomic status defined by income, education, and occupation is a major risk factor for cognitive impairment and dementia [16].

All analyzed studies underlined that eHealth wearable devices provide continuous, passive, and objective monitoring of behavioral and physiological biomarkers. Thus, they offer a critical shift toward detecting mild cognitive impairment and dementia long before traditional clinical symptoms become apparent.

All studies also agreed that wearable technology presents a promising opportunity to enhance the care for people with mild cognitive impairments by providing continuous health monitoring, real-time alerts, and improved patient autonomy. Devices as ear-based hearing aids, smart earphones or movement and gait sensors have the potential for tracking physiological parameters and support early interventions.

Devices measuring walking speed, stride length, balance, and dual-task performance capture the distinct "motor signature" often tied to cognitive impairment long before they become apparent [1, 3, 6, 7, 9, 11, 13].

Speech analysis tools, are especially useful to figure mild cognitive impairments and early signs of Alzheimer's disease [11]. Applied either in the background during phone calls or through specific voice recording exercises, they record word-finding difficulties and planning delays, reduced overall syllables-per-second or extended articulation times reflecting general processing slowdown.

Studies that monitor sleep pattern link fragmented sleep, altered sleep architecture, and irregular circadian rhythms to early cognitive decline and Alzheimer’s disease [1, 5, 8, 10, 13].

Wearable electroencephalography or direct neurophysiological measurements register real-time brainwave frequencies (alpha, beta, theta waves), serving as non-invasive indicators of cognitive load and neural irregularities. Finding such as a shift toward lower-frequency power (increased delta and theta waves) paired with a drop in higher-frequency power (decreased beta and alpha waves), shorter average duration and an increased number of ultrashort EEG microstates, etc. may forecast or even track mild cognitive impairment and/or beginning of neurodegenerative diseases [5, 12, 14].

Most studies offer potential clues where monitoring strategies might be tailored to the individual patient under the tenets of P4 medicine (predict, prevent, personalize and participate).

Most of the studies also agree that eHealth wearables are easy to apply to elderly or patients by relatives, caregivers or the person that has to be monitor. Yet, it is also underlined that now existing solutions are not always user-friendly and ergonomic for the elderly.

The analysis also highlights:

- Substantial heterogeneity among wearable devices currently used for detection of cognitive impairment –mobile phones, smart watches and/or bracelets; incontinence pad sensors, wireless in-ear EEG wearables, etc.…
- Extreme heterogeneity in recording protocols and lack of consensus for signal acquisition protocols, lack of possibility to integrate the results to the electronic health records of the patients.
- A serious problem caused by the complexity of neurophysiological biomarkers is the validation of the registrations and applied methodology, especially when the sample size is small.
- Unstable connectivity, digital inequality of elderly and patients, privacy risks and infrastructure limitations are also emphasized.

For the future, the development of a unified framework for the use of wearables for detection of mild cognitive impairment is necessary. In addition, more studies should focus on community-based recruitment to improve ecological validity and generalizability.

Another key focus for future is Artificial Intelligence (AI) integration, resp. machine learning. The latter enables the transmission and analysis of the data acquired by the device's sensors. Those studies that already applied AI, prove that machine learning and deep learning, offers new tools to uncover hidden signatures in complex biomedical data [2, 18-19].

The analysis also reveals the main challenges while applying eHealth wearables for detection of cognitive impairment as follows:

- Substantial methodological variability in the application of wearables;
- Lack of consensus for signal acquisition protocols;
- Data overload and alert fatigue, i.e. wearables generate massive daily data streams that can overwhelm both patients and caregivers;
- Accuracy and interoperability;
- Privacy and security issues.

Strengths and Limitations

The results of this meta-analysis contribute to the knowledge on evaluation and coping with cognitive impairment problems applying eHealth wearables. It brings us to lessons of digital health applications for mental health support that could be applied in the future.

The strengths of this meta-analysis are:

- The follow up PRISMA-ScR [17] guidelines;
- Selection of the most suitable databases;
- Selection of most recent studies, performed within different countries and continents, resp. ethnic groups.

However, this analysis has its limitations to list some:

- Only papers published in English were selected. This is something that the authors will correct in the next step of their research;
- Only studies published in the period 1.1.2023–1.10.2026 were chosen;
- There are missing data from some included studies, despite of the attempts to contact the corresponding authors;
- The search strategy was limited to studies where eHealth wearables and cognitive impairments were the index items. This may let us to overlook some important articles where eHealth wearables and cognitive impairments were not in the focus of the study.

Conclusions

The global aging population is rapidly increasing. Thus, the prevalence of age-related cognitive conditions, such as mild cognitive impairment, is becoming more common. Although this condition represents intermediate stages between normal aging and dementia, detecting cognitive decline earlier allows for more timely interventions and treatment plans, resulting in better medication effectiveness and lifestyle modification as lifestyle changes can help to prevent or slow the cognitive impairment.

All studies analyzed proved that eHealth wearables offer advantages over traditional assessment methods, i.e. frequency, objectivity, monitoring in natural setting.

No doubt, wearable intelligence enabled technology in cognitive impairment care will enable faster and safer preventive care, lower overall cost, improved patient-centered practice and enhanced sustainability.

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