Wearable Solutions for Patients with Parkinson's Disease

Abstract:

Prevalence of neurocognitive diseases in adult patients demands the use of wearable devices to transform the future of mental health. Recent development in wearable technology proclaimed its use in diagnosis, rehabilitation, assessment, and monitoring. This systematic review presents the state of the art of wearables used by Parkinson's disease (PD) patients or the patients who are going through a neurocognitive disorder. This article is based on PRISMA guidelines, and the literature is searched between January 2009 to January 2020 analyzing four databases: PubMed, IEEE Xplorer, Elsevier, and ISI Web of Science. For further validity of articles, a new PEDro-inspired technique is implemented. In PEDro, five statistical indicators were set to classify relevant articles and later the citations were also considered to make strong assessment of relevant articles. This led to 46 articles that met inclusion criteria. Based on them, this systematic review examines different types of wearable devices, essential in improving early diagnose and monitoring, emphasizing their role in improving the quality of life, differentiating the various fitness and gait wearable-based exercises and their impact on the regression of disease and on the motor diagnosis tests and finally addressing the available wearable insoles and their role in rehabilitation. The research findings proved that sensor based wearable devices, and specially instrumented insoles, help not only in monitoring and diagnosis but also in tracking numerous exercises and their positive impact towards the improvement of quality of life among different Parkinson and neurocognitive patients.
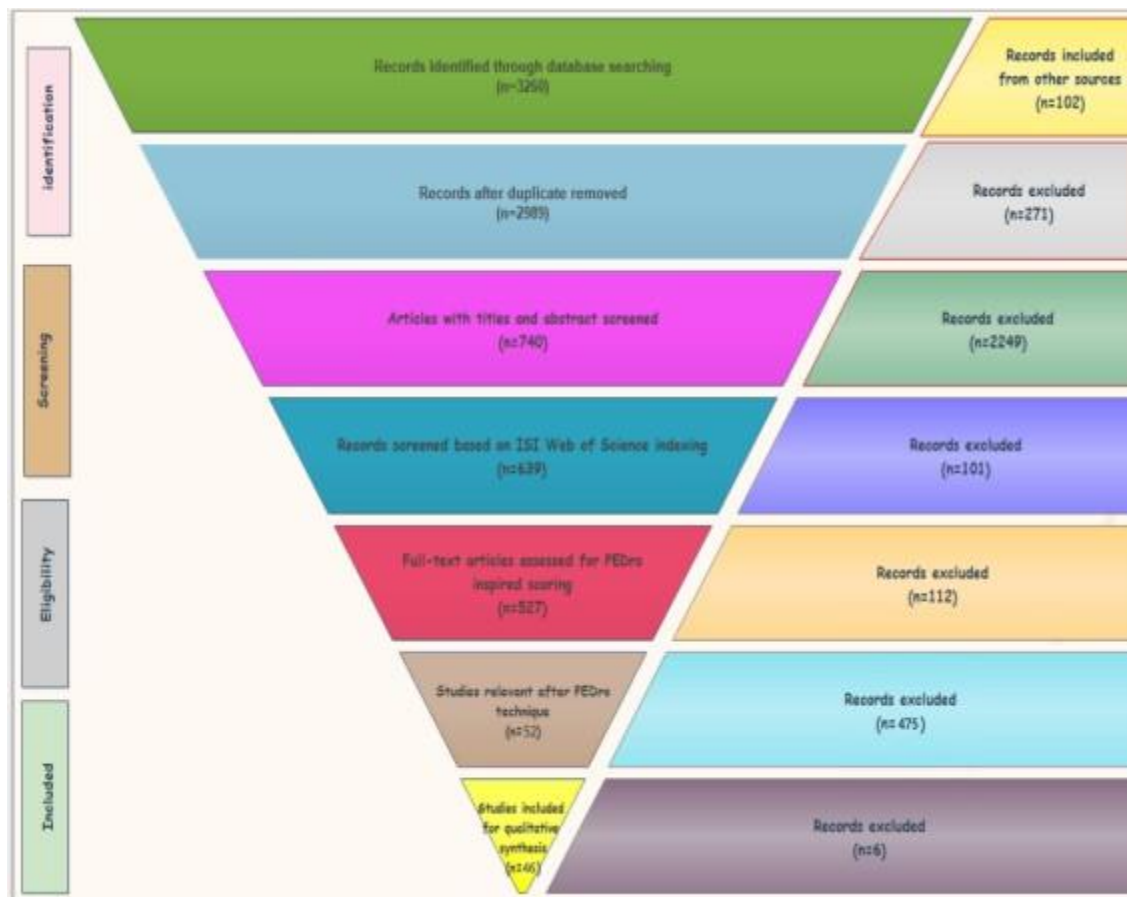
1 Introduction:

Nowadays, millions of people are bearing cognitive deterioration [1]. There is an extensive range of neurocognitive disorders specified as Alzheimer's disease, Parkinson's disease, Traumatic brain injury, Lewy body disease, Vascular disease, Frontotemporal lobar degeneration, etc. [2,3]. Comparatively, Parkinson's disease (PD) is the second most frequently observed neurodegenerative disease [4]. Around seven to ten million people in the world have Parkinson's disease. The examination of Parkinson's disease is a tricky one; research has been done for decades and still there is no robust test that serves as the best since Parkinson's disease signs and symptoms vary from person to person and its features are very similar to other illnesses [5]. PD can be investigated incorrectly and can be interpreted with other diseases. Characterization of tremors in hands and gait features plays a vital role in diagnosis and long-term monitoring of Parkinson patients.

2. Method:

Data Collection

Our systematic literature review collected publications from January 2009 to January 2020 from the following databases: Elsevier, IEEE Xplorer, and PubMed/Medline. Our search for finding relevant articles is comprised of five stages based on Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) as shown in Figures 1 and 2. In the initial stage, we used three combinations of keywords: "wearable sensors AND Parkinson disorder", "wearable sensors AND neurocognitive disorder", "Parkinson patients AND rehabilitation exercises" in the three databases mentioned above, and we got around 3158 articles as result. We also added 102 relevant articles found from other sources with these keywords and hence we got 3260 articles as shown in Table 1

In the second stage, we initially removed 271 duplicates since the same articles were found in different databases, and we also removed articles on the basis of careful analysis of titles and abstracts. In this way, 740 records were obtained as shown in Table 2. In the third stage, we filtered out the articles and considered the ones which are ISI indexed. Based on this criteria, we got 639 articles as shown in Table 3

The flow diagram shows a PRISMA-style funnel:

- **Identification**
  - Records Identified through database searching (n=3260)
  - Records included from other sources (n=102)
  - Records after duplicate removed (n=2989)
  - Records excluded (n=271)
- **Screening**
  - Articles with titles and abstract screened (n=740)
  - Records excluded (n=2249)
  - Records screened based on ISI Web of Science indexing (n=639)
  - Records excluded (n=101)
- **Eligibility**
  - Full-text articles assessed for PEDos inspired scoring (n=527)
  - Records excluded (n=112)
  - Studies relevant after PEDos technique (n=52)
  - Records excluded (n=475)
- **Included**
  - Studies included for qualitative synthesis (n=46)
  - Records excluded (n=6)

3. Early Diagnosis Wearables

The Effects of Motor Disorders on Quality of Life (QoL) Preponderance of Parkinson's and overall motor symptoms affects the QoL of PD patients very badly [11]. Gait disorders are classified according to an accepted scheme and their associations to falls. Neuro-psychological measures and QoL have been explored for decades, a fact that proved that gait impairments significantly diminish QoL. The main motor disabilities faced by PD patients are elaborated in Table 6 and Figure 3. Gait disorders are the most common among PD patients, reducing the mobility in the daily life activities and becoming worse as disease advances [12]. The difference between normal and Parkinsonism gait can be seen in Figure 3. Hence, PD leads to major walking problems, causing falls and hence leading to long-term disability and independence loss.

The role of wearables in improving early diagnosis and monitoring is further analyzed considering the great improvements brought by the wearable devices proposed by so many researchers in this field. The most promising role can be played by the wearables which are less expensive, consume less power, are unobtrusive, and provide more accurate data in diagnosing, monitoring, and managing a rehabilitation process. Wearables in PD applications may be helpful in early diagnosis, tremor, body motor fluctuations, and home and long-term assessment as discussed in [13]. Currently, PD diagnosis relies on monitoring the motor and non-motor significance and usually doctors check the severity of PD patients disease by asking them to perform specific tasks and assign them scores based on Unified Parkinson.

4. Conclusions:

In the context of fast development of wearable technologies, more and more solutions for diagnosis, rehabilitation, assessment, and monitoring of patients with Parkinson's disease have been discussed and presented in the scientific literature. This systematic review is comprised of two parts. The first one regards a quantitative analysis in which we collected more than 3000 articles from four databases, based on the PRISMA technique. We used a PEDro inspired method to reduce our set to 46 worthy articles. Furthermore, in the second part, a qualitative analysis has been realized based on recent solutions developed for PD diagnosis and rehabilitation. Considering all the factors and research works, we can conclude that motor disability of Parkinson's patients significantly reduces the QoL as it is not diagnosed at initial stages and the clinical diagnoses are based on UPDRS scaling and other clinical systems scoring that proved to be limited by individual assessment and patients' status. The existing wearable technology is playing a leading role in terms of treatment, diagnosis, and motor activity improvement of PD.

Researchers have proposed many different wearable solutions for monitoring and diagnosis of PD by putting more efforts in finding the most dominant features during gait activity such as heel off, step length, stride length, stride time, and plantar pressure. The most suitable wearable sensor devices for finding these features are wearable insoles, IMU based monitoring systems attached at lower limb, smart bands, EMG based devices, Actigraphs, GAITrite, ActivPals, and gait monitoring system using a smart-phone equipped with inertial sensors. Among all these, the insoles proved to be more dominant and useful, suggesting that these wearable solutions must be exposed to a larger population for validity. From the selected articles, it is demonstrated that repetitive intense motion activities proved to be effective for PD patients especially to those with severe motor disabilities. Great advantages are observed with treadmill and sensory motor training's but still the results depend on the optimal location, amount of training under supervision, mode of delivery, intensity of exercise, and the type of training required to get the benefits

As a high number of initiatives in the previous research shows that most of the wearable devices use uni-modal sensor or bi-modal sensors, in the future, we will investigate the effectiveness of the multi-modal sensor approach for the assessment of PD. Our next directions will also focus on the role of invasive sensors. The aforementioned technology in which sensors reside inside the patient body has been proved to be very useful providing continuous information for monitoring and also diminishing PD effects like tremor or bradykinesia. Hence, we will investigate the articles regarding the impact of invasive sensors on PD patients, challenges in operation of minimally invasive sampling techniques, their application to larger community for telemedicine or telehealthcare, and their useful deployment in healthcare industry.