Commercial Wrist Devices for Epileptic Seizure Detection: a Systematic Review

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Andrea Caroppo received his masters' degree in Computer Engineering in 2004 from the University of Lecce. From 2004 to 2006 he was researcher fellow at the Italian National Research Council (CNR), Institute of Study of Intelligent Systems for Automation (ISSIA) in Bari (Italy). His research interests were in the area of image and video processing/coding, neural networks, motion estimation in video sequences and multi-dimensional signal processing.

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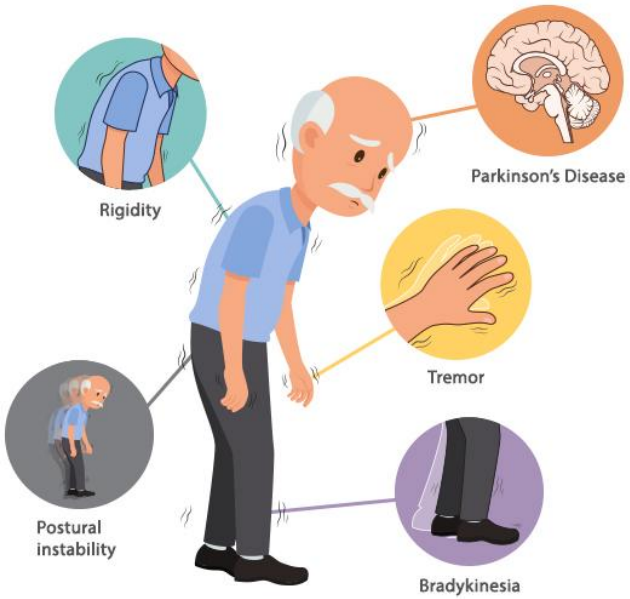
He is author of more than 50 papers in national and international journals and conference proceedings.

Introduction (1/3)

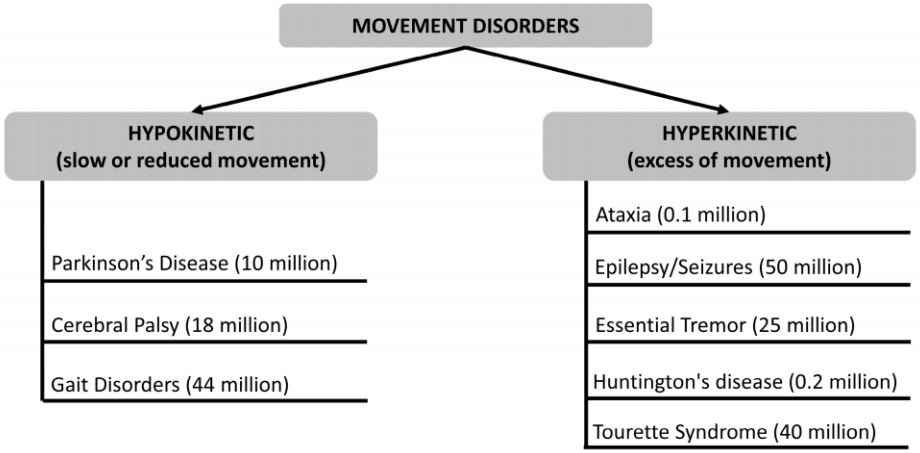
The number of admissions to hospitals or private nursing homes of patients suffering from various diseases has risen, mainly due to the aging of the world population

Production by technology companies of low-cost commercial wearable devices easy to use even for the elderly population, and that integrate sensors for acquiring data useful for vital signs estimation, activity classification, sleep quality estimation, exercise quality assessment, critical event detection, and disorders.

The most common disorders in the world's population are those of a **neurological nature**

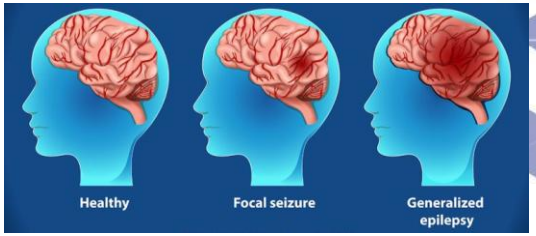


Classification of movement disorders with an approximate indication of worldwide incidence.



Introduction (2/3)

- ✓ Epilepsy, a neurological disorder characterized by recurrent seizures, affects millions of people worldwide
- ✓ Its impact extends beyond the physical realm, often influencing aspects of a patient's daily life



<u>What Causes Epilepsy?</u>

Epilepsy can result from a variety of causes, including:

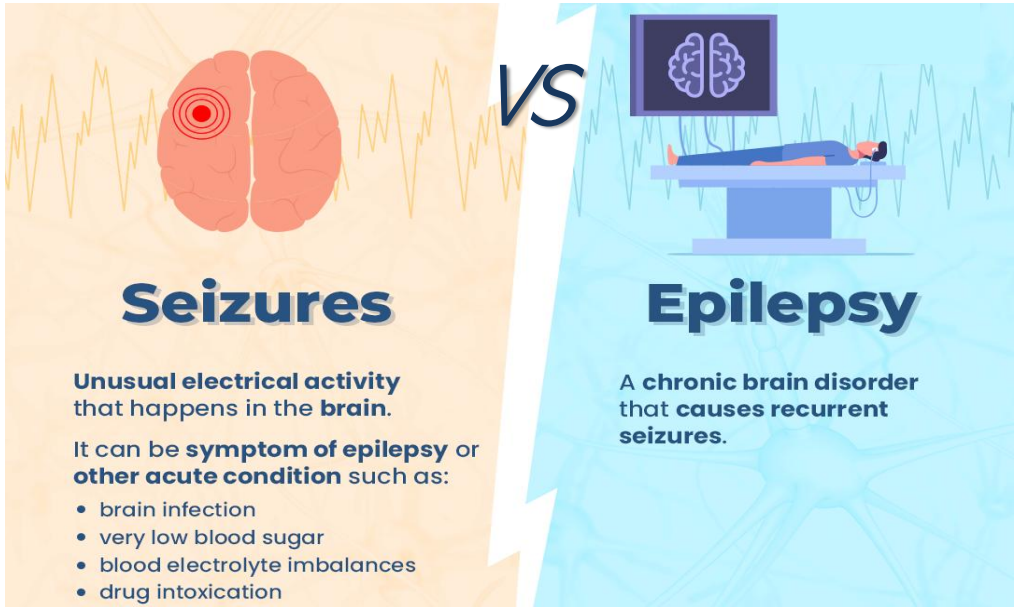
Genetic Factors – Some individuals may have a genetic predisposition to epilepsy, making it more likely to occur within certain families.

Brain Injury or Trauma – Head injuries, strokes, or other traumatic events that affect the brain can increase the risk of developing epilepsy.

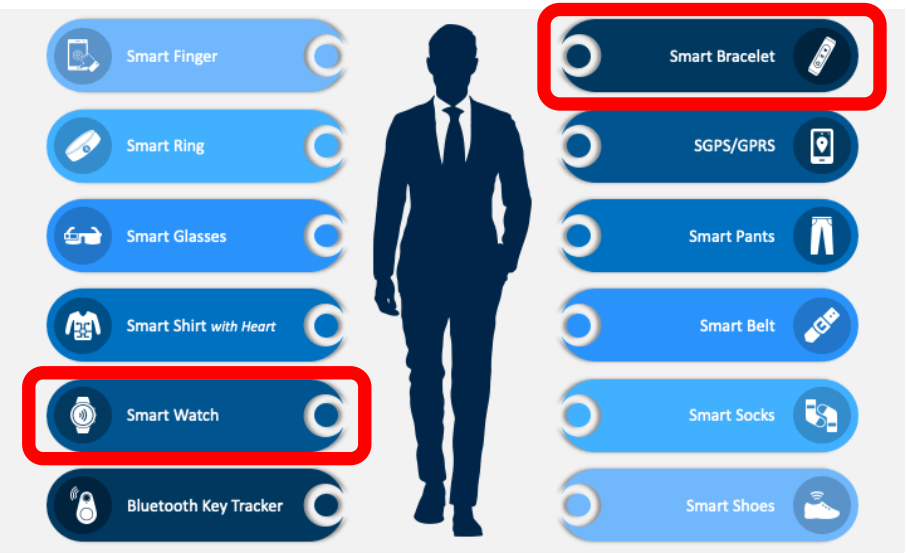
Infections – Infections such as meningitis or encephalitis can cause inflammation in the brain, triggering seizures.

Developmental Disorders – Conditions like autism and neurofibromatosis may be associated with an increased risk of epilepsy.

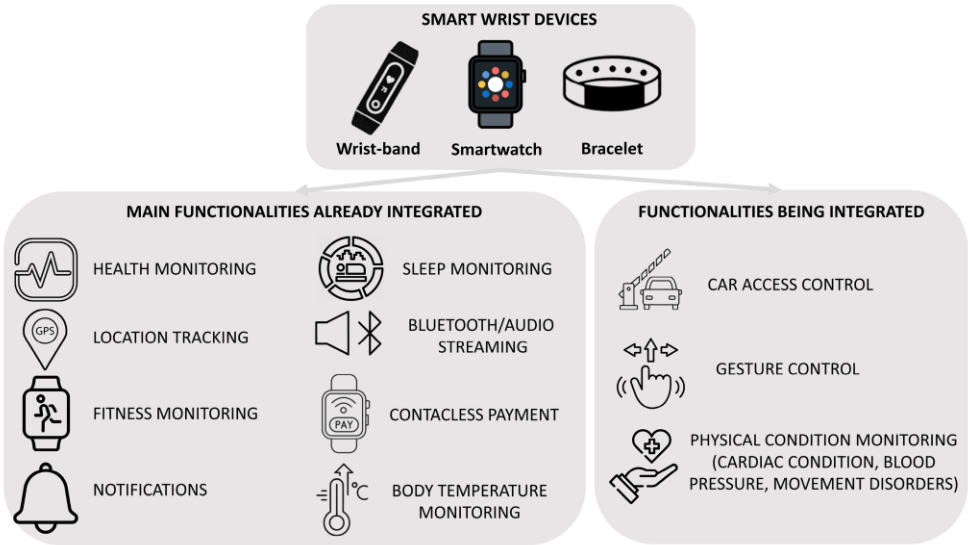
Brain Tumors – The presence of tumors in the brain can disrupt normal brain activity and lead to seizures.



Introduction (3/3)



Main functionalities (already or being integrated) for smart wrist devices in the market.



Objective of the review

- To provide a collection of the most recent research advancements made in the field of smart wrist devices for monitoring epilepsy or seizure detection.

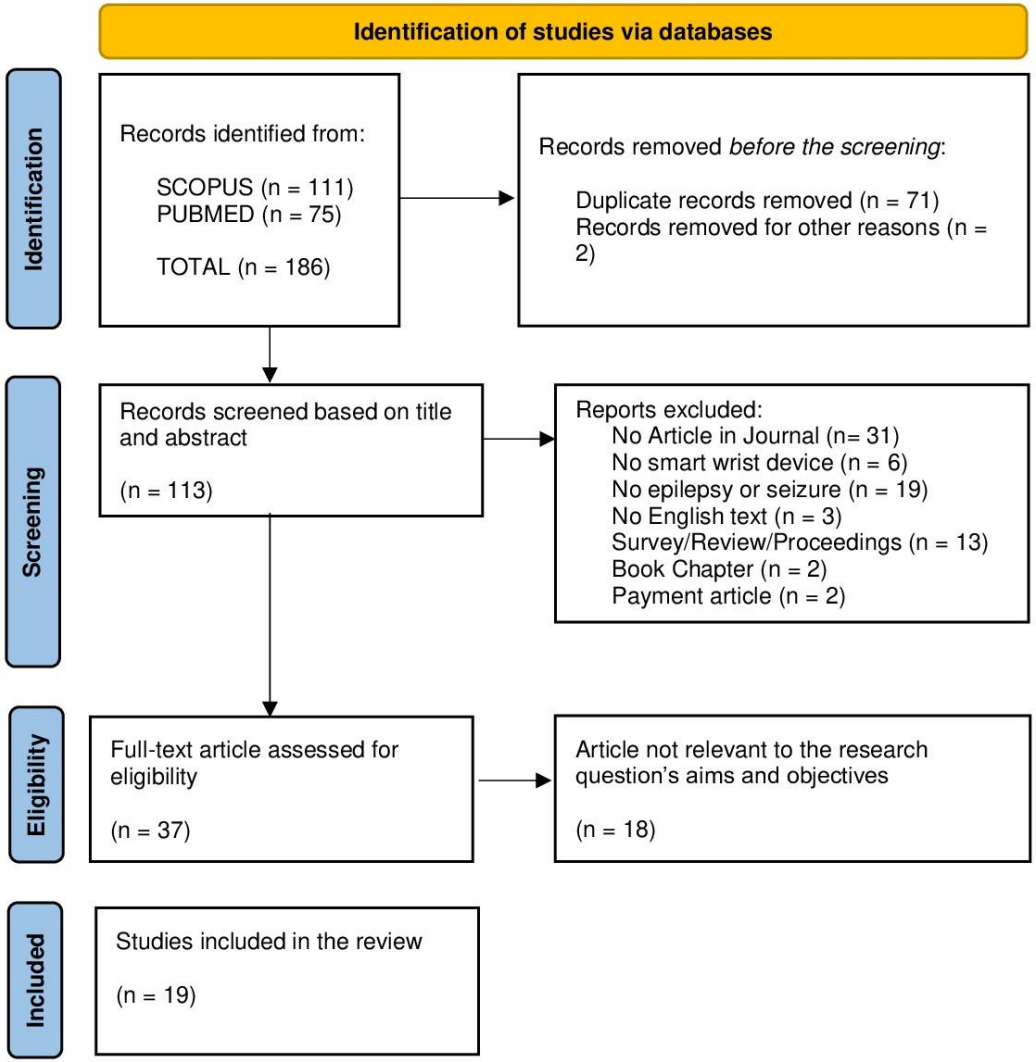
Methodology (1/2)

- Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) adopted as systematic review methodology
- Two databases were searched, including Scopus and PubMed, to identify relevant studies published from 2014 until July 2024.
- The structured queries for extracting items for analysis were selected based on the following question: "How are smartwatches, bracelets, or wristbands used to provide information about epilepsy or epileptic seizure?"

Database	Search query
Scopus	TITLE-ABS ((("Smartwatch" OR "Smartwatches" OR "Wristband" OR "Wristbands" OR "Bracelet" OR "Bracelets" OR "Smart watch" OR "Wrist-worn" OR "Wrist device" OR "Wrist devices" OR "Actigraph" OR "Apple watch" OR "Garmin" OR "Fitbit") AND ("Epilepsy" OR "Seizure")))
PubMed	((Smartwatch[Title/Abstract]) OR (Smartwatches[Title/Abstract]) OR (Wristband[Title/Abstract]) OR (Wristbands[Title/Abstract]) OR (Bracelet[Title/Abstract]) OR (Bracelets[Title/Abstract]) OR (Smart watch[Title/Abstract]) OR (Wrist-worn[Title/Abstract]) OR (Wrist device[Title/Abstract]) OR (Wrist devices[Title/Abstract]) OR (Actigraph[Title/Abstract]) OR (Apple watch[Title/Abstract]) OR (Garmin[Title/Abstract]) OR (Fitbit[Title/Abstract])) AND ((Epilepsy[Title/Abstract]) OR Seizure[Title/Abstract]))

Methodology (2/2)

Flow diagram generated with PRISMA methodology, depicting the reviewers' process of finding published data on the considered topic and how they decided whether to include it in the review.



Results (1/4)

[15] C. Dong et al., "A two-layer ensemble method for detecting epileptic seizures using a self-annotation bracelet with motor sensors," IEEE Transactions on Instrumentation and Measurement, vol. 71, pp. 1–13, 2022.

[16] S. Kusmakar, C. K. Karmakar, B. Yan, T. J. O'Brien, R. Muthuganapathy, and M. Palaniswami, "Automated detection of convulsive seizures using a wearable accelerometer device," IEEE Transactions on Biomedical Engineering, vol. 66, no. 2, pp. 421–432, 2018.

[17] K. Vandecasteele et al., "Automated epileptic seizure detection based on wearable ECG and PPG in a hospital environment," Sensors, vol. 17, no. 10, p. 2338, 2017.

[18] J. Mittlesteadt et al., "Evaluation of an activity tracker to detect seizures using machine learning," Journal of Child Neurology, vol. 35, no. 13, pp. 873–878, 2020.

[19] C. Meisel, R. El Atrache, M. Jackson, S. Schubach, C. Ufongene, and T. Loddenkemper, "Machine learning from wristband sensor data for wearable, noninvasive seizure forecasting," Epilepsia, vol. 61, no. 12, pp. 2653–2666, 2020.

[20] V. D. Naganur, S. Kusmakar, Z. Chen, M. S. Palaniswami, P. Kwan, and T. J. O'Brien,"The utility of an automated and ambulatory device for detecting and differentiating epileptic and psychogenic non-epileptic seizures," Epilepsia Open, vol. 4, no. 2, pp. 309–317, 2019.

[21] A. L. Patterson et al., "SmartWatch by SmartMonitor: assessment of seizure detection efficacy for various seizure types in children, a large prospective single-center study," Pediatric Neurology, vol. 53, no. 4, pp. 309–311, 2015.

[22] S. Kusmakar et al., "Novel features for capturing temporal variations of rhythmic limb movement to distinguish convulsive epileptic and psychogenic nonepileptic seizures," Epilepsia, vol. 60, no. 1, pp. 165–174, 2019.

[23] A. Van de Vel, K. Verhaert, and B. Ceulemans, "Critical evaluation of four different seizure detection systems tested on one patient with focal and generalized tonic and clonic seizures," Epilepsy & Behavior, vol. 37, pp. 91–94, 2014.

Results (2/4)

[24] S. A. Larsen, D. H. Johansen, and S. Beniczky, “Automated detection of tonic seizures using wearable movement sensor and artificial neural network,” Epilepsia, vol. 65, no. 9, pp. e170–e174, 2024.

[25] F. Onorati et al., “Multicenter clinical assessment of improved wearable multimodal convulsive seizure detectors,” Epilepsia, vol. 58, no. 11, pp. 1870–1879, 2017.

[26] F. Mohammadpour Touserkani et al.,“Photoplethysmographic evaluation of generalized tonic-clonic seizures,” Epilepsia, vol. 61, no. 8, pp. 1606–1616, 2020.

[27] W. Pipatpratarnporn, W. Muangthong, S. Jirasakuldej, and C. Limotai, “Wrist-worn smartwatch and predictive models for seizures,” Epilepsia, vol. 64, no. 10, pp. 2701–2713, 2023.

[28] A. Ge et al., “Seizure triggers identified postictally using a smart watch reporting system,” Epilepsy & Behavior, vol. 126, p. 108472, 2022.

[29] J. Arends et al., “Multimodal nocturnal seizure detection in a residential care setting: a long-term prospective trial,” Neurology, vol. 91, no. 21, pp. e2010–e2019, 2018.

[30] A. Biondi et al., “Feasibility and acceptability of an ultra-long-term at-home EEG monitoring system (EEG@ HOME) for people with epilepsy,” Epilepsy & Behavior, vol. 151, p. 109609, 2024.

[31] M. Nasseri et al., “Ambulatory seizure forecasting with a wrist-worn device using long-short term memory deep learning,” Scientific Reports, vol. 11, no. 1, p. 21935, 2021.

[32] W. Xiong et al., “Forecasting seizure likelihood from cycles of self-reported events and heart rate: a prospective pilot study,” EBioMedicine, vol. 93, 104656, 2023.

[33] M. E. Thompson, J. Langer, and M. Kinfe, “Seizure detection watch improves quality of life for adolescents and their families,” Epilepsy & Behavior, vol. 98, pp. 188–194, 2019.

Results (3/4)

	Commercial Device	Kind of smart wrist device	# end-users	Data Availability
[15]	no		N.A.	no
[16]	yes	Apple iPod touch	79	no
[17]	yes	Empatica E4	11	yes
[18]	yes	Fitbit Charge 2	40	no
[19]	yes	Empatica E4	69	no
[20]	yes	Apple Ipod touch	11	no
[21]	yes	SmartMonitor	41	no
[22]	yes	N.A.	79	no
[23]	yes	Epi-Care Free	1	no
[24]	yes	Epi-Care free	18	no
[25]	yes	Empatica E3 and E4	69	no
[26]	yes	Empatica E4	174	no
[27]	yes	Empatica E4	30	no
[28]	yes	Apple Watch	999	no
[29]	yes	Nightwatch	34	yes
[30]	yes	FitBit Charge 3,4,5	12	yes
[31]	yes	Empatica E4	6	no
[32]	yes	Fitbit	13	yes
[33]	yes	SmartMonitor	10	no

Empatica (E3,E4)

Epi-Care Free

Nightwatch

Results (4/4)

- A careful analysis of the articles presented in the review shows that there are still difficulties in using smart wrist devices, both commercial and non-commercial, for clinical research and treatment of epilepsy and/or seizures, despite their many benefits and prospects.

- Validation of the works in controlled contexts, therefore need for additional development and evaluation before implementation in clinical practice.

- Frail and/or elderly users forget to wear the device, in some cases not providing necessary continuous monitoring of certain indicative parameters to assess changes.

- Inability to get direct access to the raw data, some providing it exclusively by paying monthly or annual subscriptions to proprietary platforms, in some cases preventing widespread deployment of a epilepsy monitoring solution.

- Need in most cases to own not only a wrist device but also a smartphone with the functions of acquiring the raw data, processing it, and transmitting it to a cloud platform.

Conclusion…

This comprehensive review has meticulously examined the use of smart wrist devices for the detection of epileptic seizures, delving into its various dimensions and identifying both the challenges and opportunities that lie ahead for future research.

Scientific publications relevant to the topic were analysed, excluding many works considered inconsistent or with non-quality scientific content.

Analysis of the publication dates of the articles demonstrates how there is a growing interest in the topic investigated, with selected works no older than 10 years.

…and future works

Updating/extending the review through the use of additional scientific publication search engines (i.e., IEEE Explorer, Scholar, …)

Review articles on other movement disorders (Parkinson's disease, Ataxia, Essential Tremors...)

THANK YOU
ANY QUESTIONS?

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