As per UGC guidelines an electronic bar code is provided to seure your paper

International Journal for Modern Trends in Science and Technology
Volume 10, Issue 04, pages 99-105.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue04.html
DOI: https://doi.org/10.46501/IJMTST1004016

A Review on Electromyography (EMG) Pain Detection and Monitoring System

R K Raaghavi[1], R Brindha[2], T Manoj Prasath[3]

[1, 2] UG Scholar, Department of Biomedical Engineering, BIST-BIHER, Chennai.
[3]Assistant Professor, Department of Biomedical Engineering, BIST-BIHER, Chennai

To Cite this Article
R K Raaghavi, R Brindha and T Manoj Prasath, A Review on Electromyography (EMG) Pain Detection and Monitoring System, International Journal for Modern Trends in Science and Technology, 2024, 10(04), pages. 99-105. https://doi.org/10.46501/IJMTST1004016

Article Info
Received: 20 March 2024; Accepted: 06 April 2024; Published: 08 April 2024.

ABSTRACT

The potential applications of wearable e-textiles beyond healthcare, such as in sports performance monitoring and rehabilitation. It discusses the benefits of using EMG signals for personalized training programs and injury prevention in athletes. The integration of machine learning algorithms for analysing EMG data is also explored, highlighting the potential for more accurate and efficient monitoring and control of robotic exoskeletons. The challenges and limitations of current wearable e-textile technology, such as the need for improved signal processing algorithms and sensor integration. It emphasizes the importance of interdisciplinary collaboration between engineers, healthcare professionals, and researchers to further advance the field of wearable e-textiles for healthcare and beyond. In conclusion, the text underscores the transformative potential of wearable e-textiles in revolutionizing healthcare and improving quality of life for individuals with mobility impairments or chronic pain. It calls for continued research and development in this area to unlock the full potential of wearable e-textiles for monitoring EMG signals and enhancing human performance and well-being.

1. INTRODUCTION

Electromyography (EMG) onset detection methods for real-time control of robotic exoskeletons. EMG is widely used in various fields like Biomechanics, Biomedical Engineering, Neuroscience, and Rehabilitation Robotics. The study aimed to compare the performance of commonly used methods on experimental EMG data. The amplitude range of EMG signal is 0-10 mV (+5 to -5) prior to amplification. EMG signals acquire noise while traveling through different tissue. It is important to understand the characteristics of the electrical noise. Threshold-based methods were found to be the most commonly used for EMG onset detection, with Single, Double, and Adaptive Threshold methods being the most prevalent. These methods showed high accuracy in detecting muscle activity onset, with minimal error rates. However, Double Threshold method required more processing time compared to Single and Adaptive Threshold method. Its highlighted the importance of accurate and fast detection of muscle onset time for identifying movement intention, especially in real-time applications like controlling robotic exoskeletons. While the three commonly used methods proved to be accurate, Single and Adaptive

Threshold methods were faster in terms of EMG onset detection time, particularly with intramuscular EMG data. The study also noted the increasing interest in Machine Learning-based methods for detecting muscle activation onset, showing promising results. However, further research is needed to fully explore their potential for real-time applications and movement intention inference. Based on their application domain, pre-processing methods, and EMG onset detection methods. Pre-processing methods like EMG Envelope and Teager-Kaiser Energy Operator (TKEO) were commonly used to enhance the quality of EMG signals. EMG Envelope calculation was the most frequently used pre-processing method, followed by TKEO. The study emphasized the need for a standardized method for EMG onset detection to ensure reproducibility across studies and facilitate the development of novel algorithms for real-time control of wearable robots [1]. A new type of electronic material called e-textile has been developed to cool the user and increase thermal comfort. This e-textile is designed to reduce the need for cooling energy, making it a good choice for the environment. The key to this e-textile's passive cooling properties is in its design. It is made of styrene-ethylene-butylene-styrene (SEBS) non-woven elastomer microfibers containing evenly encapsulated Al2O3 particles and hot-melt nano/micro pores. This product gives the e-textile a high emissivity, meaning it has the ability to dissipate heat from the body. It also has the ability to reflect UV-visible-near-infrared radiation, helping to reflect sunlight and cool the user. The effectiveness of e-textiles in keeping the user cool has been tested in different climates. On a sunny day, the temperature can be reduced by 10.5â relative to the surrounding environment. Even on cloudy days the temperature can reach 11.3Â°C. It can be 7.0Â° cooler at night than traditional SEBS textiles. In addition to its cooling function, this e-textile can also be printed with liquid metal and used as a bioelectrode to monitor electrophysiological signals. This means it can be used to measure reliable signals such as electrocardiogram (ECG), surface electromyography (sEMG) and electroencephalography (EEG) signals. Its ability to be used underwater makes it a versatile health technology. Overall, this superstretched e-textile offers promise for zero-energy cooling of healthy-looking epidermal electronics. The ability to cool the user, combined with the ability to monitor electrophysiological signals, enables the use of many technologies that can improve human comfort and health [2].

2. DISCUSSION

The methodologies and algorithms for analysing EMG signals, emphasizing the need for advanced methods in detection, processing, and classification. A comparison study is conducted to assist researchers in developing more efficient applications. Background information on the complexity of EMG signals and the importance of advanced analysis methods is discussed. The materials and methods section includes anatomical and physiological information on EMG signals, muscle and nervous system functions, and the process of acquiring and decomposing them. The history of EMG is briefly mentioned. Overall, the article offers a comprehensive overview of EMG signal analysis and its practical applications [3]. IoT in healthcare offers benefits like accessibility, improved outcomes, and reduced costs. Remote pain monitoring aids chronic pain patients with continuous monitoring and early intervention. Wearable devices and bio-sensing tech in telemedicine are significant advancements. IoT enables remote monitoring and timely interventions, enhancing patient care and reducing healthcare system burden. An IoT-based remote pain monitoring system with a wearable device and bio-sensing facial mask can revolutionize pain assessment and management by providing real-time data for tailored treatment plans and improved outcomes [4]. The ICEHG DS provides diverse EHG records, including induced or cesarean deliveries, not found in traditional datasets. This allows researchers to analyse the influence of delivery modes on preterm birth prediction, improving model accuracy. By combining data from multiple databases, researchers gain a deeper understanding of pregnancy and childbirth, enhancing prediction accuracy. The ICEHG DS is a valuable resource for obstetrics and gynecology researchers, offering a unique opportunity to study the impact of delivery modes on preterm birth prediction and improve pregnancy monitoring for better outcomes [5]. Using surface EMG signals to detect light sleep during short naps, emphasizing the benefits of napping for 10-30 minutes. Polysomnography is complex and the traditional method for sleep measurement. The study suggests an automatic power nap device using EMG signals and an algorithm to identify sleep stages. Testing on ten subjects showed promising results, with high accuracy using a combination of features. A real-time EMG-based power nap monitoring system was proposed, effectively detecting sleep stages and waking participants after stage 2, with an average nap duration of 15 minutes [6]. The IoT stress detection and health monitoring system is an effective solution for early identification of stress-related health issues. It uses sensors and SMS alerts to help individuals manage stress levels and seek medical help. Its simple hardware and software requirements make it suitable for widespread use in healthcare. Integration with ThingSpeak allows real-time monitoring and analysis of stress levels. Future improvements may include more sensors for comprehensive health monitoring and the use of a SOC device for better performance. The system's flexibility and power efficiency make it suitable for medical camps and individuals with disabilities, showcasing its versatility and potential impact on public health. Overall, this IoT system is a significant advancement in healthcare technology, promoting proactive stress management and overall well-being [7]. Highlights the benefits of using AI in Automatic Pain Assessment (APA) in clinical settings, categorizing AI methods into behavioral-based and neurophysiology-based approaches. It emphasizes the importance of objective measures for accurate pain assessment and stresses the need for collaboration between clinicians and computer scientists to improve AI-based pain assessment tools. Additionally, it discusses the significance of explainability and ethics in AI-based pain management, emphasizing transparency and accountability in algorithm development. Overall, the text showcases AI's potential in revolutionizing pain assessment and management, underscoring the importance of collaboration, transparency, and ethical considerations [8]. Parkinson's disease causes tremors in the elderly, requiring regular clinic visits and medication. Early detection is crucial as the disease is incurable and affects daily activities. Voice analysis can aid in remote diagnosis. A system using EMG sensors, NodeMCU, and Blynk app monitors muscle activity for early treatment. The EMG sensor is attached to the left hand for monitoring, with alerts and notifications sent to patients at home. The system records muscle activity using NodeMCU, ESP8266, Muscle Sensor, and electrodes, including a help button and medication reminders. EMG data is displayed wirelessly, but stability may vary with internet and Wi-Fi usage and multiple devices on Wi-Fi can affect performance [9]. How digital technologies can revolutionize pain research, assessment, management, and treatment. The authors stress the importance of integrating digital tools to improve patient outcomes and healthcare delivery. They also highlight the impact of COVID-19 on pain research and the need for innovative solutions like remote data collection and virtual consultations. The authors advocate for addressing disparities in pain care and promoting inclusive approaches. Overall, the text provides an overview of pain research and offers insights into future opportunities for advancement [10]. 3D printing in developing EMG sensing systems for robotics and biomedical applications. It highlights challenges in EMG detection and how 3D printing allows for customized products that fit specific spaces and provide user comfort. It compares EMG illumination techniques and explores applications of 3D printed sensors in various fields. It explains the importance of EMG signals in disease diagnosis, injury prevention, and measuring muscle dysfunction. Different types of electrodes, such as dry and wet electrodes, are used in EMG devices. 3D printing technology offers advantages over traditional manufacturing, allowing for changes in electrode structure. The article also discusses the future of 3D printing in EMG sensing and challenges in this field [11]. sEMG is valuable in neurorehabilitation, exercise, sport, and ergonomics, but faces barriers in cultural acceptance, education, and technology. These barriers include disparities in acceptance and training, insufficient math and physics knowledge, equipment usability and cost, and lack of international standards. To improve clinical use, healthcare professionals need enhanced education, technology transfer, and academic opportunities. sEMG is crucial for monitoring neuromuscular pathologies, occupational therapy, and treatment planning, but its acceptance is low compared to ECG and EEG due to lack of literacy and qualified operators. Bridging the gap between research and clinical use is essential for sEMG advancement. **fig 2.1 shows the** example of the advances in sEMG detection in the last 70 years. [12]

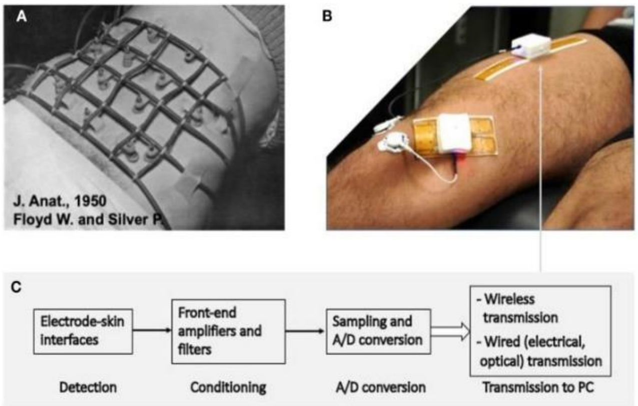

Fig 2.1 Example of the advances in sEMG detection in the last 70 years. **(A)** Electronics used for signal conditioning had the size of a suitcase. **(B)** Modern system for detection, condition, A/D conversion, and transmission of signals from sEMG. **(C)** Schematic diagram of the signal detection, conditioning, conversion, and transmission depicted in **(B)**.

This versatile electronic textile is a significant advancement in wearable technology, offering a wide range of functionalities such as recording electrophysiological data, sensing strain, and providing heating. Made from a breathable nonwoven material, it is comfortable to wear for extended periods and is antibacterial and waterproof. Its moisture permeability and water repellency make it ideal for intense physical activities, while its ability to monitor bioelectrical signals accurately is beneficial for healthcare, fitness, and sports applications. Overall, this textile combines comfort, functionality, and performance, making it a valuable tool for improving health and well-being through wearable technology [13]. E-skin in healthcare aims to replace bulky diagnostic devices with flexible wearables that mimic human skin. It has applications in medical monitoring, prosthetics, implants, robotics, and more. Key characteristics include flexibility, stretchability, self-healing, biocompatibility, and reliability. Historical context traces the evolution of e-skin from science fiction to current research, with recent trends focusing on material development, fabrication techniques, health-oriented sensors, and power management. E-skin systems involve sensing biological stimuli, data processing, transmission, and power supply, requiring flexible, stretchable, and biocompatible materials. They are valuable as in situ diagnostic tools for personalized healthcare. fig 2.2 shows the working principle of an e-skin system [14].

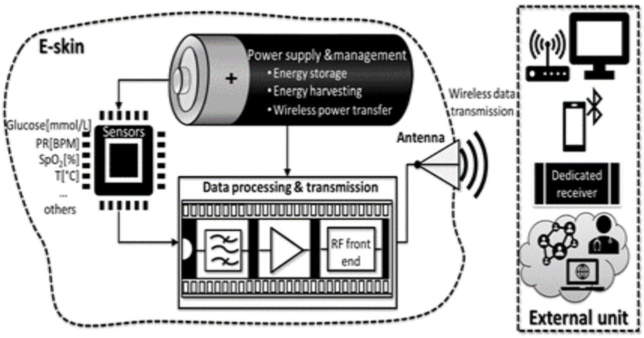

Fig 2.2 Working principle of an e-skin system.

Wearable sensors improve personalized healthcare with data transmission. Neural networks analyse sensor data for health feedback. Wearable sensors reduce hospitalizations and costs for convenient monitoring. Biosensors address healthcare challenges like diabetic management. Sensors can be attached to the body or embedded in everyday items. Smartphones and smartwatches monitor health and intervene. Future wearables may include smart clothing for specific conditions. Various sensor designs, like sweat biosensors, are being developed for real-time analysis [15]. The review highlights the importance of wearable sensors and portable devices in monitoring physical activity in rehabilitation, sports, and wellness, with a focus on advancements in EEG, ECG, and EMG signal monitoring systems. It discusses the role of sensors in tele-rehabilitation for precise physiological signal analysis and explores future innovations in monitoring systems. The paper also explores the use of biomedical wearable sensors in diagnosing, treating, and monitoring diseases and movement disorders, as well as their benefits in clinical, non-clinical, and sporting environments. Telerehabilitation programs, including home exercises and monitoring devices, have shown effectiveness for post-COVID-19 patients. The review concludes with a summary of recent developments in wearable sensors for rehabilitation and the literature on EMG signal acquisition devices in rehabilitation [16]. Using MMG signals to assess muscle activity under electrical stimulation, highlighting its reliability compared to voluntary contraction. It identified 62 studies covering aspects such as fatigue, torque, force, and electrode development. Despite the potential for errors, MMG and NMES approaches show promise in assessing muscle function, with applications in prosthetics control. The review also discussed using NMES-induced training to improve muscle integrity and force generation. Further research, including machine learning techniques, is needed to enhance understanding and reliability in assessing muscle performance [17]. Researchers have created a flexible and durable skin-integrated silicon microneedle electrode (SSME) for long-term EMG monitoring. The SSME, inspired by plant thorns, is biocompatible and stretchable, able to stretch up to 36% and proven safe through cytotoxicity tests. Compared to wet electrodes, the SSME offers similar recording ability during movement and better performance for long-term use. It can be used in wearable healthcare monitoring, myoelectric prostheses, and human-computer interfaces, with painless attachment to the skin and reduced contact impedance for stable detection. The customizable and chemically stable SSME provides accurate and reliable EMG monitoring for effective human-computer interfaces [18]. For pain and stress detection using wearable sensors, discussing mechanisms and correlations. Various signals are examined for healthcare monitoring, with suggestions for modern computing techniques. The mechanisms of pain transmission and gate control theory are explained. Challenges in pain testing design and limitations in medical field detection are discussed. Wearable sensors for stress detection are explored, emphasizing an integrated approach to pain and stress management. The review underscores the potential of wearable sensors in improving pain and stress detection and management. [19].

3. METHODOLOGY

The study presents the fabrication of an e-textile bioelectrode array for whole-body electromyography monitoring. The array consists of screen-printed silver paste wiring, a thermoplastic polyurethane insulation layer, and ionic liquid gel-embedded knit textile pads. Challenges include forming an insulation layer on the wiring and fixing the ionic liquid gel due to the properties of the materials used. The proposed structure includes a laser-patterned hot-melt urethane film attached to the silver paste wiring to avoid disconnection and improve adhesive force. A 6x3 bioelectrode array is fabricated for electromyography, with impedance matching that of medical electrodes and improved adhesive force of the ionic liquid gel. fig 3.1 shows the proposed device structure of the e-textile bioelectrode array for EMG measurements.

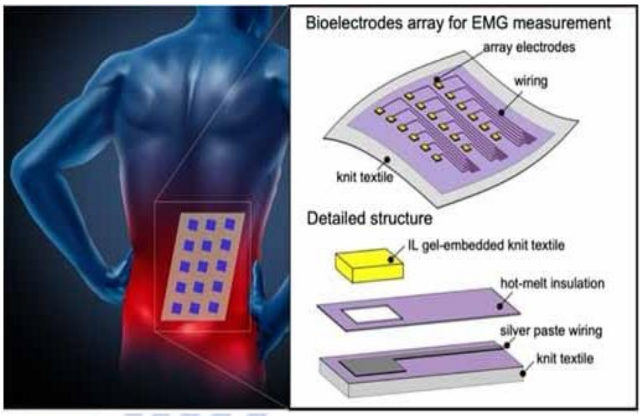

Fig 3.1 Proposed device structure of the e-textile bioelectrode array for EMG measurements.

The development of smart wearable technology incorporating bioelectrodes has gained attention for digitizing health data and providing medical diagnoses. E-textile technologies offer advantages in whole-body vital data monitoring compared to traditional smartwatches. The study focuses on long-term wet gel bioelectrode arrays for applications like back pain measurement. An ionic liquid gel is proposed as an ideal electrode material due to its properties, but challenges in patterning and fixing the gel on the array exist. The study proposes a fabrication process using polyurethane film, screen-printed silver paste, and laser-cut insulation layer to address these challenges.The fabrication process involves screen printing silver paste on polyurethane film, bonding it to knit textile, laser-cutting an insulation layer, and attaching the textile for the ionic liquid gel. Evaluation parameters include patterning resolution, impedance measurements, and adhesive strength. The study aims to develop a bioelectrode array for EMG measurements, including the flexion relaxation phenomenon, for back pain diagnosis and healthcare applications. The proposed structure and manufacturing process show promise for improving wearable medical monitoring devices. fig 3.2 shows the forearm EMG measurement with wrist flexion [20].

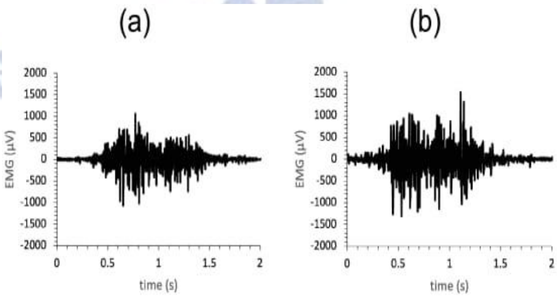

Fig 3.2 Forearm EMG measurement with wrist flexion (a): fabric electrode (b): medical electrode.

4. CONCLUSION

The study presents the fabrication of an e-textile bioelectrode array for whole-body electromyography monitoring. The array consists of screen-printed silver paste wiring, a thermoplastic polyurethane insulation layer, and ionic liquid gel-embedded knit textile pads. Challenges include forming an insulation layer on the wiring and fixing the ionic liquid gel due to the properties of the materials used. The proposed structure includes a laser-patterned hot-melt urethane film attached to the silver paste wiring to avoid disconnection and improve adhesive force. A 6x3 bioelectrode array is fabricated for electromyography, with impedance matching that of medical electrodes and improved adhesive force of the ionic liquid gel.The development of smart wearable technology incorporating bioelectrodes has gained attention for digitizing health data and providing medical diagnoses. E-textile technologies offer advantages in whole-body vital data monitoring compared to traditional smartwatches. The study focuses on long-term wet gel bioelectrode arrays for applications like back pain measurement. An ionic liquid gel is proposed as an ideal electrode material due to its properties, but challenges in patterning and fixing the gel on the array exist. The study proposes a fabrication process using polyurethane film, screen-printed silver paste, and laser-cut insulation layer to address these challenges.The fabrication process involves screen printing silver paste on polyurethane film, bonding it to knit textile, laser-cutting an insulation layer, and attaching the textile for the ionic liquid gel. Evaluation parameters include patterning resolution, impedance measurements, and adhesive strength. The study aims to develop a bioelectrode array for EMG measurements, including the flexion relaxation phenomenon, for back pain diagnosis and healthcare applications. The proposed structure and manufacturing process show promise for improving wearable medical monitoring devices [21].

5. FUTURE SCOPE

The future scope for a Innovative e-textile bioelectrode arrays hold immense potential for revolutionizing cutaneous electromyography (EMG) in both pain detection and therapy. These advancements represent a convergence of textile technology, bioelectronics, and healthcare, offering a promising avenue for non-invasive, wearable solutions. In terms of pain detection, these bioelectrode arrays can provide real-time monitoring of muscle activity, enabling early detection and assessment of various musculoskeletal conditions and injuries. Moreover, the integration of e-textiles enhances comfort and flexibility, facilitating prolonged and unobtrusive monitoring. Beyond detection, the therapeutic applications are equally compelling. By leveraging biofeedback mechanisms, these arrays can deliver targeted electrical stimulation to mitigate pain, promote muscle rehabilitation, and improve overall mobility. Furthermore, the seamless integration of textile-based electrodes with wearable devices opens doors for personalized and adaptive therapy regimens, tailored to individual needs and responses. As research and development in this field progress, we can anticipate advancements in sensor sensitivity, signal processing algorithms, and miniaturization, further enhancing the efficacy and accessibility of e-textile bioelectrode arrays for cutaneous EMG-based pain management and therapy. Such innovations hold the promise of not only improving patient outcomes but also fostering a paradigm shift towards preventive and personalized healthcare.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] Camila R. Carvalho, J. Marvin Fernández, Antonio J. del Ama, Filipe Oliveira Barroso, Juan C. Moreno, "Review of electromyography onset detection methods for real-time control of robotic exoskeletons," Journal of NeuroEngineering and Rehabilitation., vol. 20, no. 141, Oct. 2023, doi: 10.1186/s12984-023-01268-8

[2] Muhammad Al-Ayyad, Hamza Abu Owida, Roberto De Fazio, Bassam Al-Naami, Paolo Visconti, "Electromyography Monitoring Systems in Rehabilitation: A Review of Clinical Applications, Wearable Devices and Signal Acquisition Methodologies," Electronics., vol. 12, no. 1520, pp. 1-35, Mar. 2023, doi: 10.3390/electronics12071520.

[3] M.B.I Raez, M. S. Hussain, F. Mohd-Yasin, "Techniques of EMG signal analysis: detection, processing, classification and applications," Biological Procedures Online., vol. 8, no. 163, pp. 11–35 Dec. 2006, doi: 10.1251/bpo1.

[4] Geng Yang, Mingzhe Jiang, Wei Ouyang, Guangchao Ji, Haibo Xie, Amir M. Rahmani, Pasi Liljeberg, Hannu Tenhunen, "IoT-based Remote Pain Monitoring System: from Device to Cloud Platform,"

IEEE Journal of Biomedical and Health Informatics., vol. 22, no. 6, pp. 1711 – 1719, Nov. 2018, doi: 10.1109/JBHI.2017.2776351.
[5] Franc Jager, "An open dataset with electrohysterogram records of pregnancies ending in induced and cesarean section delivery," Scientific Data., vol.10, no. 669, Oct. 2023, doi: 10.1038/s41597-023-02581.
[6] Wachiraporn Aiamklin, Yutana Jewajinda1 , Yunyong Punsawad, "Light Sleep Detection based on Surface Electromyography Signals for Nap Monitoring," International journal of biology and biomedical engineering., Vol. 16, pp. 140-145, Jan. 2022, doi: 10.46300/91011.2022.16.18202.
[7] N.Padmaja, A.Anusha, D.V.S Manaswi, B.Sathish Kumar, "IOT Based Stress Detection and Health Monitoring System," Helix - The Scientific Explorer | Peer Reviewed Bimonthly International Journal., vol. 10, no. 2, pp. 161-167, Mar 2020, doi: 10.29042/2020-10-2-161-167.
[8] Marco Cascella, Daniela Schiavo, Arturo Cuomo, Alessandro Ottaiano, Francesco Perri, Renato Patrone, Sara Migliarelli, Elena Giovanna Bignami, Alessandro Vittori,Francesco Cutugno, "Automatic Pain Assessment: Research Methods and Perspectives," Pain Research and Management., vol. 1, Jun. 2023, doi: 10.1155/2023/6018736.
[9] Nisrina Firyal Fadhlannisa, Basari Basari, "Design of Wireless Electromyography Monitoring System for Muscle Activity Detection on Parkinson's Disease," International Conference on Smart Technology and Applications (ICoSTA) Feb. 2020, doi:10.1109/ICoSTA48221.2020.1570609982
[10] Sara E. Berger A, lexis T. Baria, "Assessing Pain Research: A Narrative Review of Emerging Pain Methods, Their Technological Implications, and Opportunities for Multidisciplinary Approaches," Frontiers in Pain Research., vol. 3, Jun.2022, doi: 10.3389/fpain.2022.8962762022.
[11] Haotian Su, Hadi Moeinnia, Woo Soo Kim, "3D Printed Electromyography Sensing Systems," Advanced Sensor Research., vol. 2, no. 9, April. 2023, doi: 10.1002/adsr.202300003.
[12] Isabella Campanini, Catherine Disselhorst-Klug, William Z. Rymer, Roberto Merletti, "Surface EMG in Clinical Assessment and Neurorehabilitation: Barriers Limiting Its Use," Frontiers in Neurology., vol. 11, no. 934, Sep. 2020, doi: 10.3389/fneur.2020.00934.
[13] Yidong peng a, Jiancheng Dong a, Jiahui Sun a, Yanheng Mao a, Yuxi Zhang a, Jiayan Long a, Le Li a, Chao Zhang b, Yan Zhao c, Hengyi Lu d, Hai-Long Qian e, Xiu-Ping Yan e, Jianhua Zhao f, Fangneng Wang f, Yunpeng Huang a, Tianxi Liu a, "Multimodal health monitoring via a hierarchical and ultrastretchable all-in-one electronic textile," Nano Energy., vol. 110, Jun.2023, doi: 10.1016/j.nanoen.2023.108374.
[14] Alina-Cristina Bunea, Violeta Dediu, Edwin Alexandru Laszlo, Florian Pistrițu, Mihaela Carp, Florina Silvia Iliescu, Octavian Narcis Ionescu, Ciprian Iliescu, "E-Skin: The Dawn of a New Era of On-Body Monitoring Systems," Micromachines., vol. 12, no. 91, Sep. 2021, doi: 10.3390/mi12091091
[15] Aaron Asael Smith, Rui Li, Zion Tsz Ho Tse, "Reshaping healthcare with wearable biosensors," Scientific Reports., vol. 13, Mar. 2023, doi: 10.1038/s41598-022-26951-z.
[16] Arrigo Palumbo, Patrizia Vizza, Barbara Calabrese, Nicola Ielpo "Biopotential Signal Monitoring Systems in Rehabilitation: A Review," Sensors, vol. 21, Oct. 2021, doi: 10.3390/s21217172.
[17] Raphael Uwamahoro, Kenneth Sundaraj, Indra Devi Subramaniam, "Assessment of muscle activity using electrical stimulation and mechanomyography: a systematic review," BioMedical Engineering OnLine., vol. 20, Jan. 2021, doi: 10.1186/s12938-020-00840-w.
[18] Huawei Ji, Mingyu Wang, Yutong Wang, Zhouheng Wang, Yinji Ma, Lanlan Liu, Honglei Zhou, Ze Xu, Xian Wang, Ying Chen, Xue Feng, "Skin-integrated, biocompatible, and stretchable silicon microneedle electrode for long-term EMG monitoring in motion scenario," npj Flexible Electronics., vol. 7, Oct.2023, doi: 10.1038/s41528-023-00279-8.
[19] Jerry Chen, Maysam Abbod, Jiann-Shing Shieh, "Pain and Stress Detection Using Wearable Sensors and Devices—A Review," Sensors, vol. 21, no. 4, Feb.2021, doi: 10.3390/s21041030.
[20] Naoto Tomita, Seiichi Takamatsu, Toshihiro Itoh, "Fabrication of an E-Textile Bioelectrode Array With Screen-Printed Wiring and an Ionic Liquid Gel Toward Cutaneous Whole-Body Electromyography," IEEE Access., vol. 11, pp. 68421-68427, Jan. 2023, doi: 10.1109/ACCESS.2023.3291782
[21] Yidong peng a, Jiancheng Dong, Yiting Zhang, Yuxi Zhang, Jiayan Long, Jiahui Sun, Tianxi Liu, Yunpeng Huang, "Thermally comfortable epidermal bioelectrodes based on ultrastretchable and passive radiative cooling e-textiles," Nano Energy., vol. 120, Feb. 2024, doi: 10.1016/j.nanoen.2023.109143