GOODBYE BACK PAIN: THE T-SHIRT OF THE FUTURE THAT LISTENS TO YOUR BODY

CONTACT DETAILS:

Research Results Transfer Office-OTRI
University of Alicante
Tel.: +34 96 590 99 59
Email: areaempresas@ua.es
http://innoua.ua.es

ABSTRACT

Researchers from the Department of Physical Education and Sports at the University of Alicante have developed a new smart textile garment that allows real-time and objective monitoring of the lumbar spine.

The main innovation lies in the 3D electrodes embroidered on the textile itself with a special configuration which, combined with state-of-the-art sensors and appropriate training with advanced Artificial Intelligence models, measure different bioelectrical signals and movements, eliminating subjectivity in the diagnosis of pain. The main advantages include correct diagnosis and functional assessment, high precision, comfort and ease of use, as well as customisation to the user's needs, among others.

This technology has applications in hospitals, rehabilitation clinics, mutual insurance companies, gyms and research. We are looking for companies interested in acquiring this technology for its commercial exploitation through patent licensing agreements.

INTRODUCTION

The real-time detection, diagnosis and monitoring of low back injuries is complex. On the one hand, because it is necessary to perform punctual measurements outside daily activity and, on the other hand, because it has a subjective component associated with the user's perception of pain.

In addition, the biometric or bioelectrical signals commonly used to detect or monitor injuries, such as electrocardiogram (ECG), heart rate variability (HRV), surface electromyography (sEMG) or electrodermal activity (EDA), offer a high variability, so the information provided must be carefully analysed and interpreted to be of practical use, and this variability is related to the quality of the signal captured by the electrodes responsible for acquiring the signals.

In this sense, without a proper correlation between the bioelectrical signals and the movement, position or posture of the user, it is not possible to achieve an objective assessment of the condition of the lumbar spine.

The technologies currently available on the market do not provide an accurate and objective assessment, either because they are based on a single biometric signal, or because they use electrodes attached to the skin that make the equipment less operational and the signals acquired less accurate, or because it is not possible to effectively measure the curvature of the lumbar region. In addition, the Machine Learning algorithms used are only used to monitor the signals, so that the current devices cannot identify the presence and degree of pain objectively.

Consequently, to date, there is no commercial device that can accurately measure all the necessary biomedical parameters, nor does it combine all these measurements with posture and movement monitoring for an objective functional assessment of injuries or the condition of the lumbar spine.

With the aim of solving the above need, an **intelligent textile garment has been developed that allows functional assessment and continuous real-time monitoring of the lumbar spine**, thus solving the problem of subjectivity in the diagnosis of back pain.

The components of the garment, as well as its operation, are detailed below:

1. Components of the garment:

• **Flexible textile body**: serves as a support for the other components, allowing adaptation to the wearer's body. It can be made of different textile materials (cellulosic, polymeric, both combinations) and construction (openwork, elastic, etc.), prioritising comfort and breathability. As an example of garment configuration, it could be in the form of a waistcoat, short-sleeved T-shirt or long-sleeved T-shirt.

• **Integrated textile electrodes**: Embroidered directly on the fabric, they capture different bioelectric signals (ECG, HRV, sEMG, EDA) in a non-invasive way. Their three-dimensional configuration, with multiple layers of conductive yarn and a foam interlayer, ensures optimal skin contact and a high quality signal, minimising noise and inaccuracies. In long-sleeved garments, an EDA electrode can be included in the palm of the hand to improve conductivity. ECG electrodes are placed on the chest and sEMG electrodes on the back, coinciding with the relevant muscles.

• **Electrode configuration**: Different conductive wires are used in a multilayer structure and with different orientations to ensure homogeneous conductivity. The intermediate foam between the layers provides volume and continuous contact with the skin.

• **IMU inertial sensors**: At least two units, each with an accelerometer and a 3-axis gyroscope, record the user's movements and postures, including the curvature of the back. The combination of these sensors with other bioelectrical signals allows for a more complete assessment.

• **Control electronics**: Acquires, processes and digitises the signals from the electrodes and IMU sensors. Includes an analogue-to-digital converter with multiple input channels.

• **Battery**: Powers the electronic components.

• **Data transmission system**: Allows communication between the garment and an external device (server, computer, phone, tablet) for subsequent data management and visualisation.

• Optionally, a **PPG sensor** (photoplethysmography): For double validation of heart rate measurement and/or blood pressure monitoring.

2. Assessment and monitoring system:

• **Software**: Receives and stores the garment data. It uses Big Data and Artificial Intelligence (AI) techniques for analysis.

• **Data tagging**: Software allows labelling of bioelectrical and movement signal data according to the user's perception of pain (e.g. 'severe pain', 'mild pain', 'no pain') during a series of guided physical activities.

• **AI model training**: With the labelled data, a multi-layer Machine Learning model is trained (neural networks, Bayesian networks, decision trees, support vector machines, genetic algorithms, regression).

• **Real-time monitoring**: The software compares the new garment data with the trained model to predict the user's lumbar spine condition and pain level, eliminating subjectivity.

• **Communication of results**: An application on the external device displays the results to the user or the professional.

3. Procedure for use:

1. **Start-up**: The user puts on the smart textile garment.

2. **System check**: Check that the system is turned on and that the ECG signal is being captured correctly. If there are any problems, the connection, battery or electrodes are checked.

3. **Physical activities**: The user performs a series of guided exercises involving bending, twisting and extension movements of the lower back to measure the patient's efforts and sensations in a variety of situations.

4. **Data capture**: Simultaneously, textile electrodes capture bioelectrical signals (EDA, sEMG, ECG), and IMU sensors record the user's movements and postures.

5. **Processing and digitisation**: The control electronics process and digitise the signals captured by the sensors.

6. **Data transmission**: The processed data is transmitted to an electronic device.

7. **Reception and storage**: The software installed in the device receives and stores the data.

8. **Pain recording**: The user is asked if he/she experiences pain during the exercises. If the answer is yes, the level of pain is recorded in the application (severe pain or mild pain). If there is no pain, monitoring is continued.

9. **Data tagging**: The software tags the data with the level of pain recorded by the user, which is crucial for training the AI model.

10. **Database storage**: The labelled data is stored in a database for further analysis and training of the AI model.

11. **AI model training**: A multi-layer Machine Learning model is used to learn to associate bioelectrical signals and motion

data with different levels of pain.

12. **Trained model**: A trained AI model is obtained and ready to make predictions.

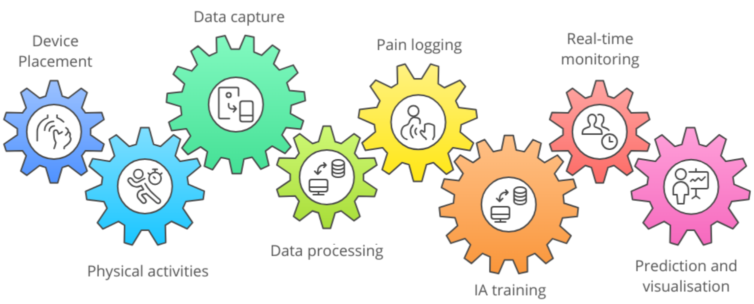
13. **Real-time monitoring**: The system receives new data from the garment in real time while the user is wearing it.

14. **Preprocessing and inference**: The software preprocesses the new data and feeds it into the trained AI model to obtain a prediction of the state of the lumbar spine and the level of pain.

15. **Visualisation of results**: The application displays the results to the user or the health professional.

16. **Continue monitoring**: The monitoring cycle continues, allowing continuous follow-up of the user's condition.

A process flow diagram is shown below as an overview (*see Picture 1*):



Picture 1: Flow chart of the procedure

ADVANTAGES AND INNOVATIVE ASPECTS

ADVANTAGES OF THE TECHNOLOGY

This novel smart textile garment offers the following **advantages**:

• It allows **lumbar pain to be detected objectively** based on a scale, eliminating the subjective component associated with the perception of pain through the application of artificial intelligence.

• It allows an **assessment and functional classification** of the lesions or the state of the lumbar spine.

• It can **accurately measure** all the necessary biomedical and biomechanical parameters, including detecting the curvature of the back thanks to IMV sensors.

• The garment is **comfortable** and **easy to wear**.

• The information provided is **very reliable** thanks to the textile electrodes integrated in the garment itself, which can pick up various bioelectrical signals from the wearer.

• The EDA measurement on the palm of the hand provides **better conductivity** compared to other areas of the body, as the conductivity of the skin is added to the conductivity of the sweat from the hand, which has a large number of sweat glands.

• The textile electrodes have an innovative three-dimensional configuration which results in a **better quality** of the acquired signals compared to flat or two-dimensional electrodes, **minimising noise and inaccuracies** in the signals.

• The three-dimensional configuration of the electrode achieved with the foam insert ensures intimate and continuous contact with the user's skin, resulting in **optimal quality** of the signals acquired by the electrode.

• The different embroidery layers of the three-dimensional electrode ensure a **homogeneous distribution** of conductivity.

• External **electromagnetic interference** can be **reduced** and even **eliminated**.

• **The amplitude of the signal is increased by up to 6 times**, which makes it easier to identify the characteristic waves of the various bioelectric signals.

• **Signal ripple is reduced**, reaching a point where it does not interfere with the identification of small amplitude waves such as the P wave of the electrocardiogram.

• Continuous monitoring allows for **long-term follow-up**.

• The **personalisation of the system** stands out, as the Artificial Intelligence model is trained with the user's own data.

• Early detection **enables prevention**.

• **Adaptation to treatment** is improved.

INNOVATIVE ASPECTS OF THE TECHNOLOGY

The main innovation lies in the **three-dimensional electrodes integrated into the textile garment itself**, which allow different bioelectrical signals or medical data to be captured from the user. The combination of these signals with the posture and movement data additionally collected by the garment allows both an **objective assessment** and the **monitoring of the subsequent treatment**, which can be modified according to the results that are subsequently recorded. The textile electrode has a **specific**

embroidery configuration that ensures a homogeneous distribution of conductivity, **ensuring excellent quality in the bioelectric signal**.

In addition, the invention uses **Artificial Intelligence and Big Data tools**, which allows further study and knowledge of the mechanisms and causes involved in low back pain. By analysing this information, it is possible to establish **strategies for its prevention**, as well as possible **treatments**.

The combination of the different physiological signals together with the monitoring of the user's movement and posture, in addition to the use of Artificial Intelligence, makes the system capable of carrying out the **functional assessment and monitoring of the lumbar spine in an objective manner**.

CURRENT STATE OF DEVELOPMENT

The technology is at a stage of maturity corresponding to **TRL = 4** (Technology Readiness Level).

A **prototype** of the smart textile garment has been successfully developed in the form of a **long-sleeved T-shirt** with a central zip closure where the sleeves have a fingerless glove-like extension that covers the palm of the hand, so that the two electrodes for EDA signal acquisition are positioned in contact with the palm of the user's hand; the electrodes for ECG signal acquisition are located in the chest area, and the electrodes for sEMG signal acquisition are located in the lumbar and abdominal area (*see Figure 1*):

Figure 1: Prototype of the smart textile garment.

Below is a detail of the sleeve extension of the smart textile garment with the electrodes measuring the EDA signal embroidered on it, as well as an image of the sleeve extension on the wearer's hand, with the electrodes covered by an additional portion of fabric (*see Figure 2*):

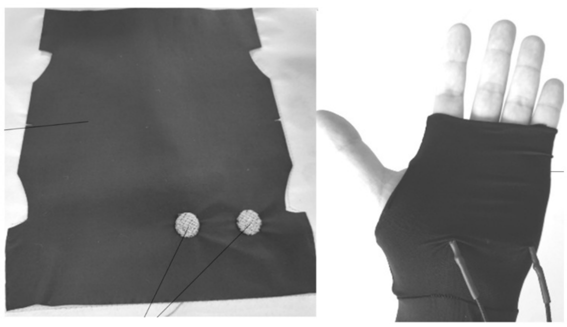


Figure 2: Detail of the sleeve extension of the textile garment with two electrodes.

Finally, a comparison is made between an **example of an ECG signal** measured with a **flat two-dimensional textile electrode** that provides poor contact with the user's skin (resulting in ripple noise due to permanent electromagnetic interference, This effect is amplified by a tendency of movement caused by the user's own breathing), compared to an example of an ECG signal measured with a **three-dimensional textile electrode embroidered on the textile garment** itself that prevents the electrode from sliding on the skin, thus increasing the electrode-skin conductivity and improving the quality of the signal (*see Figure 3*):

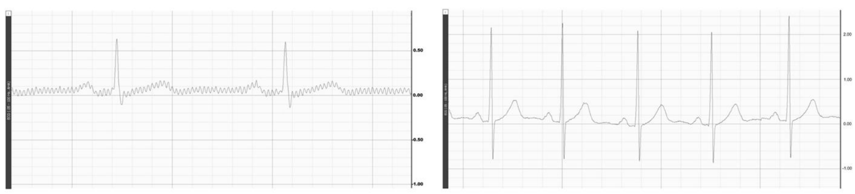


Figure 3: ECG signal measured with a flat electrode versus that measured with a three-dimensional embroidered textile electrode, respectively.

MARKET APPLICATIONS

The present invention refers to an intelligent textile garment or complement with the capacity to monitor movements, postures and physiological signals for its application in the **prevention, detection and treatment of lumbar or back injuries**, classifying the patient's sensations objectively on the basis of a scale (it makes it possible to know whether or not he or she is suffering pain, as well as the degree of pain).

It is, therefore, an innovative tool with the capacity for the **continuous monitoring of patients with illnesses causing back pain** which can be very interesting for the following sectors:

- Hospitals.
- Clinics.
- Rehabilitation.
- Mutual insurance companies.
- Gyms with specialised technical staff.
- Research.

COLLABORATION SOUGHT

Companies interested in acquiring this technology for **commercial exploitation** through patent **licensing agreements** are sought.

Company profile sought:

- Textile companies.
- Electronics companies.
- Companies that develop and market health and/or sports software.

INTELLECTUAL PROPERTY RIGHTS

The present invention is protected through **patent application**:

- Patent title: *"Prenda textil inteligente, sistema y procedimiento de valoración funcional y monitorización de la columna lumbar empleando dicha prenda textil inteligente".*
- Application number: P202430770.
- Application date: 26th September 2024.

MARKET APPLICATION (3)

Footwear and Textile
Materials and Nanotechnology
Medicine and Health