ISSN 2007-9737

Wearable Technology for Posture Correction: A Smart Approach to Health Prevention

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Abstract. This paper presents a proposal for a pervasive wearable system designed to prevent health issues related to poor body posture. At the intersection of computational philosophy and human-centered design, this system exemplifies how technology can enhance human well-being. The mobile application integrated within this system helps users avoid spinal damage caused by incorrect posture during daily activities, reflecting a commitment to improving quality of life through technological intervention. In our modern age, individuals habitually maintain poor back posture without precautions, leading to significant and long-lasting damage. This system offers a solution rooted in scientific rigor and philosophical consideration of human health. The proposed embedded system features real-time monitoring capabilities, utilizing a sophisticated planning algorithm to detect when the user's spine is under strain during daily activities. This proactive approach aligns with the philosophical tenet that prevention is better than cure. Additionally, the mobile application provides animations and sample videos to address potential adverse effects on the spine, offering methods to improve and rehabilitate overall spinal health. This system demonstrates how computational advancements can serve humanity, fostering a symbiotic relationship between technology and human health.

Keywords. Digital technology healthcare, wearable computing, pervasive computing, real-time system, embedded system.

1 Introduction

As mentioned in Mark Weiser [1], communication between wireless networks today is of great importance in the computing environment and in the area of contemporary technology in the environment that surrounds us, making new technologies adhere to our daily life environments in an easy and simple way to handle. Ubiquitous computing is the most widely used technology in computational research and is directed in educational and research environments, and today it is involved in business with salable products such as entertainment and uses as exemplified by the triple helix model [2]. However, like any modern technology, there are advantages and disadvantages when addressing compatibility problems of technological platforms in public and private sectors.

In this research and development work, an alternative way to manage physical health treatments is proposed, focused on body posture. Posture plays an important role in the treatment and prevention of body health, this is because a person's inadequate posture can cause serious physical disorders and reduce quality of life as mentioned in [3].

In our daily activities, a person's body adjusts to different positions and movements and therefore adapts to different situations. But poor posture can cause musculoskeletal problems, causing serious health problems. For this reason, education is essential in the application of strategies to improve posture. In [4] it has been shown that improper posture contributes to back pain, muscle fatigue, which induces poor breathing and digestive function.

In [5] it is mentioned that incorrect posture can cause malfunctions in various parts of the body

ISSN 2007-9737

that can be in the medium or long term. Likewise, a study was also carried out on the prolonged use of electronic devices and a sedentary posture that have increased this type of problems in both young people and adults, which promotes the use of new technologies to correct and prevent habits that help and do not harm these conditions.

This proposed project focuses on the area of physiotherapy, for the contribution of improving or regulating the functions that the body performs in kinesiology or also known as the study of the movement of the human body, and which is fundamental in the psychological aspects that allows, in a preventive way, to achieve better body health. As mentioned in [6] in the area of physical health, the movement and posture of the human body are influenced by individual habits as well as natural physical factors, which means that a general approach to these aspects is needed.

People's activities today are more sitting in front of a computer, standing incorrectly or doing physical work without proper precautions. As discussed in [7], poor posture in a person causes overload on the spine and causes serious ailments to the human body, from muscle discomfort to kyphosis, scoliosis, or hernias. This is why this type of problem is of great importance; in recent studies, maintaining an inadequate posture affects the body's biomechanics and blood circulation. For this reason, as mentioned in [8], the health area and specifically physiotherapy has begun to integrate new technologies such as wearables or devices attached to clothing, as well as mobile applications that respond in real time, to help people's health, not so much for patients with posture problems, but also for the prevention of people in general. With a combination of technological tools and physiotherapy techniques in the health area, there is general and constant monitoring that helps provide health education that helps our daily lives.

A mobile application is proposed just to monitor a digital t-shirt with wearable tendencies. This ubiquitous device continuously monitors a person's posture with the help of the App, identifying incorrect posture after daily activities and supporting an improvement in the rehabilitation exercises of a patient or a person with back health problems. With this proposal, it is possible to have better control over the progress of patients in the field of physiotherapy. Likewise, it allows the objective evaluation of the patient's condition by making adjustments to the treatment according to the recorded evolution, since applications focused on this topic evaluate the recovery time that can be in an accident, where the project can measure the speed of recovery and how effective the proposed exercises are and make updates to them. [8]

Furthermore, the use of technology makes detailed monitoring easier for an expert in the health area and gives rise to a personalized treatment, this increases the patient's motivation and commitment to the recovery process. [9]

2 State of the Art

According to the IMSS (Mexican Social Security Institute), pain in the lumbar region ranks third among the ten leading causes for seeking physical medicine and rehabilitation services. People between the ages of 25 and 45 are the most affected by lower back pain due to posture problems when lifting or carrying heavy objects, sitting, lying down, or because of falls, bruises, and traffic accidents. This issue also affects students and individuals who spend most of their time sitting in an incorrect position [10].

These health problems are increasingly being addressed with the support of new technologies, mainly by mobile device and mobile apps. As shown in [11], wearable monitor vital signs with an embedded system with an electrocardiogram. This signal is widely adopted to diagnose and evaluate the main health risk and chronic heart disease. This work focuses on the review of portable monitoring systems in the form of wireless, mobile and remote technologies related to older adults. In addition, efficiency, user acceptability, strategies and recommendation for improving current monitoring systems are present with a general description of the design and modeling.

The results of the review suggest that most research in monitoring systems is focused on the elderly and this technology has been adopted to facilitate the care. And finally, it is shown that the way in which mobile telemedicine systems have involved an advance in textile-based portable wireless systems could guarantee a better quality of medical care.

In [12], it is shown that it is possible to identify individual personality traits and measure group performance in a Post- Anesthesia Care Unit (PACU) using portable sensors. A group of 67 nurses from a hospital in the Boston, USA, area were instrumented with sociometric badges capable of measuring physical activity, speech activity, face-to-face interaction and physical proximity. Using the data collected with these sensors, the average daily length of stay (LOS) and the number of delays were estimated. The use of widespread technology in health care management has the potential to improve the performance of the organization by allowing health care providers to identify bottlenecks and ineffective behaviors. We present experimental results that show that it is possible to identify individual personality traits and measure group performance (reflected in the average LOS and the number of delays) from low level sensor data.

The electronic systems that are integrated into the clothes can serve us in a very discreet and natural way. By being positioned close to the body, they facilitate seamless and intuitive human-computer interaction. An integration of electronics into clothing can be achieved by joining conventional electronic components to clothing. However, humans prefer to use textiles instead of hard boxes; Therefore, together with the availability of integrated computing in the textile sector, the need for an interconnection based on the textile sector has also emerged.

To transmit signals at high frequency, we need high bandwidth and sufficient signal integrity. The materials must be compatible textile machinery, and the resulting materials must be robust for weaving, washing, and using tensions. Textiles used for clothing should be made of thin and elastic fibers to be comfortable and lightweight.

Textile technologies have been developed to manufacture fabrics with conductive fibers that meet the processability, resistivity, and comfort requirements. The question that remains is whether the electrical performance is adequate for signal transmission. The field of wearable biomedical systems based on smart textiles (ST-WBS) has generated much interest in research and business communities since its inception in the mid-1990s. However, technology has not yet entered the market and has realized its original objective of improving people's quality of life through improved biomedical monitoring in real time.

In [13] a framework is proposed to analyze the transition of ST-WBS (patient centered components) from research to reality. They describe the main components of an ST-WBS. We then analyze the key issues that encompass the technical, medical, economic, public and commercial policy aspects from the points of view of various stakeholders in an action plan for the transition of ST-WBS from research to reality. The technology in clothing stands out in several research papers in the health area, another example can be seen in [13], which presents a portable cardiopulmonary monitoring system called Detection Shirt. The detection jacket consists of a shirt with integrated sensors for physiological monitoring, a data acquisition unit (DAQU) and a PC-based software suite. The series can acquire a series of vital signs data such as electrocardiogram (ECG), ribcage (RC) and abdominal breathing photoplethysmogram (AB), SpO2 and posture / activities. Physiological data is stored on a microSD memory card and then analyzed offline to extract parameters such as heart rate (HR), respiratory rate, SpO2, tidal volume (TV), wave transit time of the pulse (PWTT) and the arrhythmia respiratory sinus (RSA). In the Sensing-Shirt system, the ECG is acquired by means of active electrodes.

PPG [14] and ECG [15] are sampled in a 16-bit high-speed ADC at 500 Hz for accurate PWTT calculation. The pulse amplitude modulation technique used in this research work for signal conditioning both in respiratory inductive plethysmography [16] and in PPG circuits to reduce energy consumption. This proposed prototype is powered by 2 AA batteries with 1600 mAh capacity; the entire system can run more than 48 hours continuously without interruption. Basic performance tests show that this system can capture PPG signals effectively, and extract parameters such as HR, respiratory rate. SpO2 and TV accurately. This advanced outpatient monitoring system can be used both in home health care and in scientific research.

Protection and aesthetics are the two common characteristics typically associated with textiles such as clothing. However, with the rapidly changing needs of today’s consumers, a third is on the rise: the intelligence hat, which is being integrated into fabrics to produce interactive products or textiles (or i-textiles). The term electronic textiles, or e-textiles, are used to denote the kind of fabric structures that integrate electronic elements with textiles and can detect changes in their environment and respond to them. This new class of portable electronic system in being designed to meet new and innovative applications in the fields of military, public safety, medical care, space exploration, sports and physical fitness for the consumer. The objective of this document is to focus on recent advances in the field of smart textiles and pay special attention to materials and their manufacturing process.

Each technique shows advantages and disadvantages, and the objective of this study is to improve the general usability of smart clothing products by reviewing all the developments that have been made in this case to straighten the path for future research and research in this field. The idea of Ubiquitous and wearable computing describes the computer-electronic systems that will be applicable in everyday attire as an intelligent personal assistant soon. Therefore, such portable electronic devices must maintain their professional objective under the requirements of normal use, which may impose severe mechanical deformation of the underlying garment / substrate. A talented approach to reduce the rigidity of electronic textiles and improve their usability is to replace PCBs with flexible electronic products [17].

On the other hand, as commented in [18], smart textiles have emerged as a technology contributing to the area of health, adapting electronic and computational devices or components in the fabrics of clothing to carry out real-time monitoring, helping to detect early diseases and thus intervene to improve the health of users.

Recent advances in the development of 3D electronic textile systems based on microfibers that improve skin contact have achieved low independence without the use of conductive gels.

This system allows real-time monitoring of electrophysiological signals, such as electrocardiograms (ECG) and electromyograms (EMG), even during high-intensity activities or in underwater conditions. Furthermore, it has been implemented in clinical settings for simultaneous monitoring of maternal ECG signals and uterine electromyography, providing valuable data for maternal health [19].

Another important work can be seen in [20], in smart clothing that is bathed in deep learning that is designed for precise monitoring to provide the best sleeping conditions. That is to say, the fabric in contact with human skin captures the signs of skin tension without this garment being so tight and the device not being in a specific position.

Despite its enormous potential, the incorporation of e-textiles in the healthcare field faces multiple challenges that hinder its widespread adoption. One of the main challenges lies in ensuring that the electronic components integrated into garments are capable of withstanding frequent washing, constant flexing and mechanical wear without compromising their performance [21]. In addition, it is essential to develop electronic circuits that consume little energy and are highly efficient, with the aim of extending battery life and minimizing the need for frequent recharges.

Another major obstacle is moving from the prototype phase to mass production without losing economic viability or manufacturing efficiency. To facilitate the implementation of these devices in the health sector, it is key to establish standards and regulations that guarantee their safety, connectivity and data protection. Likewise, the design of clothing that is comfortable, flexible and non-invasive plays a fundamental role in its acceptance by users and its incorporation into daily life.

To address these challenges, future research should focus on the development of durable, washable, and biocompatible materials capable of retaining sensor functionality after multiple uses. It is also crucial to explore innovative technologies for energy harvesting and ultra-low power electronic circuit design, in order to improve the autonomy of these devices.

Optimizing manufacturing processes, for example through roll-to-roll printing, could facilitate mass production of e-textiles at a more affordable cost. In addition, collaboration with regulatory entities will be key to define regulations that ensure the security, effectiveness and privacy of the information collected. Finally, a user-centered approach, incorporating consumer input into the design and development of these products, will contribute to the creation of smart garments that are not only functional, but also comfortable, attractive and easy to wear.

In short, although electronic textiles have the potential to transform healthcare through continuous monitoring and personalization of treatments, it is essential to overcome these challenges to achieve their effective integration into the conventional healthcare system [22.]

3 Application Architecture

In the realm of design and techniques for digital technologies, several proposals and research agendas have emerged, each addressing different aspects and considerations.

One proposal, discussed in [23], emphasizes the importance of having access to new information and utilizing computing devices to foster creativity and positive results. However, it also acknowledges the risks associated with information overload and potential stress caused by excessive use of digital tools.

Another study, presented in [24], focuses on the design of dynamic and complex practices using Building Information Modeling (BIM) as a technological framework. This empirical investigation highlights the organizational aspects of digital innovation and explores the multi-layered nature of digital technology configuration. By refining the concept of accessibility and employing an iterative approach, the study aims to unlock the potential of digital technology as a central element in digital innovation.

Furthermore, [25] proposes a research agenda that centers on the role of dynamic capabilities and ethical considerations in the context of digital transformation. It suggests that further exploration of these areas is crucial for strategic research. Similarly, [26] presents an agenda for future research, highlighting the ongoing debates and issues that require deeper examination. Notably, the increasingly complex interaction between human and technological agents is a topic deserving attention.

Finally, [27] introduces an approach that analyzes both existing and new digital technologies. It emphasizes the integration of various relationships into a concept of transformation, particularly in digitizing manufacturing systems. The study also discusses the evaluation of identified interactions and the need for a measurement system to assess their effectiveness.

These proposals and research agendas contribute to our understanding of the design and utilization of digital technologies. They shed light

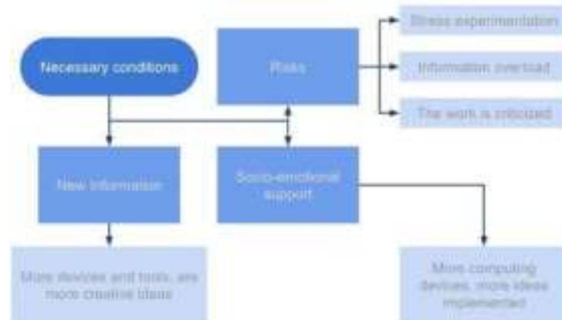

Fig. 1. Technological project design proposal

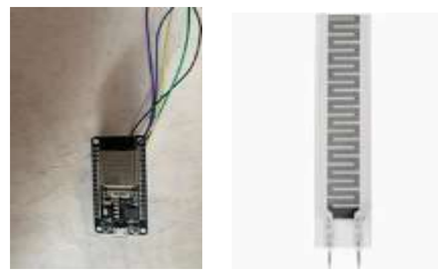

Fig. 2. Sensors

on various aspects such as creativity, organizational dynamics, ethical considerations, and the transformative potential of digital innovation. By addressing these areas, we can advance our knowledge and enhance the effectiveness of digital technology in different domains.

A wearable device has been designed and developed to detect patterns of poor posture and monitor patients in back and neck rehabilitation through a mobile application. The objectives of this project include evaluating the pathologies that our product can address and preventing the development of pathologies caused by bad posture in the cervical spine. To tackle this issue, a specialized t-shirt was developed, equipped with technological devices capable of measuring changes in people's posture. The t-shirt incorporates sensors and an accelerometer to capture relevant data. The values collected by these sensors are wirelessly transmitted via Bluetooth to a dedicated mobile application.

The mobile application plays a crucial role in receiving and processing the sensor data. It analyzes the information to determine whether the person is maintaining an appropriate posture. If the application detects an incorrect posture persisting over a significant time interval, it notifies the user and provides guidance on how to correct their posture. Furthermore, the application keeps a record of the user's posture history, enabling the analysis of generated data to identify potential trends or risks associated with poor posture and its impact on health.

To ensure effective monitoring, the sensors have been strategically placed on the upper back, as this area is commonly prone to incorrect positioning. Specifically, two flex sensors were positioned from the upper vertebra of the cervical region to the eighth vertebra of the thoracic region, as depicted in Fig. 1.

In the prototype presented in this work, Bluetooth technology was utilized for communication between two types of mobile devices using the master-slave paradigm. The objective was to transmit information from the wearable shirt to a smartphone, employing the HC-06 module as the master and the HC-05 configured as the slave. Conversely, if communication between two wearables is desired, an HC-05 module configured as the master and an HC-06 as the slave would be employed.

The development board utilized in this project is an Open Hardware electronic board that incorporates a reprogrammable microcontroller, enabling easy connections between the microcontroller and various sensors and actuators. For optimal performance and convenience, Stainless Medium Conductive thread was utilized in this prototype, as suggested in [28]. This thread, composed entirely of stainless steel with a 316L stainless steel support capacity, proved to be thin, strong, and smooth. It consists of three layers, thicker than polyester or cotton but still thin enough to be sewn by hand using medium eye needles or by asewing machine capable of handling heavy thread. Due to its strength and softness, it is well-suited for portable and electronic textile projects. With a relatively low resistivity of 10 ohms per foot, it can be used to control LEDs and other electronic components that consume less than 100 mA. Furthermore, since it is made of stainless-steel fibers, it does not oxidize like silver.4

The flex sensor (see Fig. 2) exhibits a change in resistance when bent. By employing a voltage divider, this sensor can provide an analog output ranging fr om 0 to 5 volts. The flex sensor utilized in this project corresponds to a patented Spectra Symbol technology. Under normal resting conditions (without bending), the sensor has a resistance of 30 kohms. However, when bent at a 90-degree angle, its resistance increases to 70 kohms. The connector pins of the sensor have a 0.1-inch spacing [29].

The MPUG050 is a 6-degrees-of-freedom (6-DoF) inertial measurement unit (IMU) that combines a 3-axis accelerometer and gyroscope. This sensor is widely utilized in various applications such as navigation, goniometry, stabilization, and more. It finds extensive use in scientific and engineering environments, particularly in drone control and fuzzy logic, as mentioned in the studies [34] and [30]. The MPUG050 has been specifically chosen for its capabilities.

Acceleration refers to the rate of change of velocity over time, which can be represented by the equation 1:

$$\alpha = \frac{dv}{dt}, \tag{1}$$

Accelerometers employ MEMS (Micro Electromechanical Systems) technology to measure acceleration, operating similarly to a spring-mass system. The force acting on the mass can be expressed as:

$$F=m\cdot a, \tag{2}$$

where F is the force, m is the mass, and a is the acceleration. With the assistance of an accelerometer, we can effectively gauge acceleration, even when there is no apparent motion, as the device continuously registers the acceleration due to gravity (g≈9.81 m/s2). By leveraging the accelerometer's capabilities, we can derive indirect measurements, such as determining speed through integrating acceleration over time:

$$V(t)=\int a(t)dt+V0, \tag{3}$$

where V0 is the initial velocity. Further, we can calculate displacement by integrating velocity over time:

$$x(t)=\int V(t)dt+x0, \tag{4}$$

where x0 is the initial position.

Since gyroscopes utilize MEMS (Micro-Electro-Mechanical Systems) to measure angular velocity using the Coriolis effect [32], they are employed for measuring angular velocity (ω). The angular velocity can be integrated over time to determine the angular displacement:

$$\theta(t)=\int\omega(t)dt+\theta 0, \quad (5)$$

where θ0 is the initial angular position.

To address the need for correcting poor posture in individuals, a t-shirt embedded with flex sensors was designed to capture changes in spinal posture. Flex sensors measure the bending or flexing of an object, and their resistance changes with the amount of bend, providing data that can be used to calculate the angle of flexion:

$$Rflex=R0+k\cdot\Delta\theta, \quad (6)$$

where Rflex is the resistance of the flex sensor, R0 is the baseline resistance, k is the sensor's constant, and Δθ is the change in the angle of flexion.

Simultaneously, a system capable of processing the sensor data was developed. This computer system can receive real- time information and notify the user if they maintain an incorrect position for an extended period, thereby alerting them to correct their posture. To facilitate user interaction with the collected data and potential future health issues, a mobile application was created. The application provides a graphical representation of the captured positions and potential damages, as depicted in Figure 3. By visualizing the data, users can understand their posture patterns and make necessary adjustments to prevent long-term health issues.

With the assistance of an accelerometer, we can effectively gauge acceleration, even when there is no apparent motion, as the device continuously registers the acceleration due to gravity. By leveraging the accelerometer's capabilities, we can derive indirect measurements, such as determining speed through integrating acceleration over time, or calculating displacement by integrating it once more, with the prerequisite of possessing initial speed and position information, respectively [31].

Since gyroscopes utilize MEMS (Micro-Electro-Mechanical Systems) to measure angular velocity using the Coriolis effect [32], they are employed for measuring angular velocity. By integrating the angular velocity over time, we can determine the angular displacement (or angular position if the initial reference point is known). To address the need for correcting poor posture in individuals, a t-shirt embedded with flex sensors was designed to capture changes in spinal posture. Simultaneously, a system capable of processing the sensor data was developed. This computer system can receive real- time information and notifying the user if they maintain an incorrect position for an extended period, thereby alerting them to correct their posture. To facilitate user interaction with the collected data and potential future health issues, a mobile application was created. The application provides a graphical representation of the captured positions and potential damages, as depicted in Figure 3.

Fig. 3. Shirt-wearable.

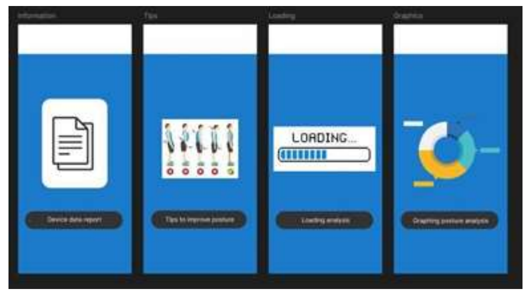

Fig. 4. App to shirt-wearable.

In the initial prototype (Fig. 4), the placement of sensors in specific areas was carefully considered. As mentioned earlier, the upper back region is often prone to incorrect posture. Therefore, two flex sensors were strategically placed from the upper vertebrae of the cervical region to vertebra 8 of the thoracic region. These flex sensors effectively capture changes in the upper 15 vertebrae of the spine.

The arrangement of components can be observed in three distinct parts. Part 1 represents the placement of flex sensors, responsible for measuring the posture changes in the targeted vertebrae. Part 2 illustrates the wiring connections between the sensors and the Arduino Lilypad development board. Lastly, part 3 showcases the development board itself, which plays a crucial role in collecting sensor data and transmitting it via a Bluetooth module to the mobile application.

5 Conclusions

This study introduces an innovative wearable system designed to mitigate health issues arising from poor posture. Integrating advanced sensor technology and real-time data processing, the system exemplifies the convergence of digital health and wearable computing. By monitoring and correcting posture, it serves as a testament to how technology can address everyday health challenges.

From a computational philosophy perspective, this system embodies the notion of human-computer symbiosis. It represents an ongoing dialogue between the biological and digital realms, where technology enhances human capabilities and addresses physical limitations. In this symbiotic relationship, the wearable device acts not merely as a tool but as an extension of the human body, continually interacting with the user to promote better health outcomes.

Moreover, the system's real-time monitoring and feedback mechanisms align with the proactive approach to health management, emphasizing prevention over cure. This proactive stance is rooted in the belief that timely intervention can significantly reduce the risk of chronic health issues, thereby enhancing the quality of life. The wearable technology thus acts as a guardian of health, vigilant and responsive to the user's physical state.

Furthermore, the system's design reflects a deep understanding of humanistic principles. It acknowledges the user's daily experiences and the subtle impact of posture on overall well-being. By providing intuitive feedback and personalized recommendations, it respects the individuality of each user, fostering a more empathetic and user-centric approach to health technology. This respect for individuality is crucial in a world where technological solutions are often one-size-fits-all. The system's ability to tailor its feedback and recommendations to each user's unique needs highlights a significant advancement in personalized healthcare.

In the broader context of societal health, this system could have far-reaching implications. Poor posture is a widespread issue with cumulative effects that strain healthcare systems and diminish the quality of life for many individuals. By addressing this issue at the individual level, the wearable system has the potential to alleviate some of the broader societal burdens associated with musculoskeletal disorders. This ripple effect showcases the power of individualized technological interventions in contributing to public health.

The philosophical implications of this wearable technology extend beyond its immediate health benefits. It prompts us to reconsider our relationship with technology and our bodies. The system suggests a future where technology is seamlessly integrated into our daily lives, enhancing our natural capabilities and helping us lead healthier lives. This vision aligns with the concept of transhumanism, where human abilities are augmented through technological means. However, it also emphasizes the importance of maintaining a balance where technology serves to enhance rather than dominate human experience.

In essence, this wearable system is not just a technical innovation; it is a philosophical statement about the role of technology in human life. It highlights the potential of computational advancements to not only solve practical problems but also enhance the human experience, creating a future where technology and humanity coexist in a mutually beneficial harmony. By addressing the pervasive issue of poor posture, this system sets a precedent for future developments in wearable health technology, emphasizing the importance of integrating computational sophistication with humanistic values.

In conclusion, the development of this wearable system for posture correction represents a significant stride in health technology. It is a harmonious blend of computational power and human-centered design, poised to make a meaningful impact on individual health and well-being. As we look to the future, this system serves as a beacon, guiding us toward a world where technology and humanity advance hand in hand, each enhancing the other in a dance of mutual benefit and continuous improvement.

Acknowledgments

We extend our sincere gratitude to the Laboratory of Technological Innovation at Benemérita Universidad Autónoma de Puebla for their invaluable support throughout the development of this research.

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Article received on 09/06/2025; accepted on 04/10/2025.
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