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SPINAL BRACES TO PREVENT OCCUPATIONAL BACK PAIN

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ABSTRACT-

Back pain is the most common problems among the working individuals. Lower back pain is the major complaint, consumes a high percentage of occupational physician firms. It has a great part in work absenteeism and continues to be a major health burden among individuals. Medical science is unable to clearly identify between pain caused by work and due to other possible activities. Occupational back pain is experienced by most people at some part of their lives and is very costly to both the health care and the industry. A major non-Medicative method of prevention of back pain is considered to be good posture maintenance. To support the good posture we are designing a brace which sense the flexion in the spinal curvature which alerts the person and helps in regaining the posture.

Key Words: Back pain, Spinal brace, Flexion.

I. INTRODUCTION

The text discusses the use of wireless sensors to detect spine curvature. The study was conducted by Azin Fathi and Kevin Curran and published in October 2017. The objective was to develop a non-invasive method for diagnosing and monitoring spine deformities. The study found that the wireless sensor recorded changes in length and stretch, which were used to calculate the lumbar motion angles.

The results showed that the wearable sheet stretch sensors effectively measured lumbar motion angles. The method provided accurate and reliable measurements, enhancing our understanding of lumbar spine motion.

A significant finding of the study is that the wearable sheet stretch sensors can be a practical tool for assessing lumbar motion angles in clinical settings. This can be particularly valuable for diagnosing and monitoring conditions related to the lumbar spine, such as low back pain or spinal disorders.

In conclusion, this study presents a method for measuring lumbar motion angles using wearable sheet stretch sensors. The method proved effective in providing accurate measurements and has potential applications in clinical settings. Further research and validation are necessary to establish the reliability and usefulness of this method.

The patent is about a posture monitoring system (US 20150038881 A1) that tracks and analyzes a person's posture in real-time. It uses a wearable device and sensors to collect data on the body's position and movement. The data is then analyzed by a processing unit, which provides feedback to the user. The system can also store and analyze posture data over time, and uses machine learning algorithms to improve accuracy. Maintaining good posture is important for health, and the system aims to help users correct their posture and prevent health issues. It stands out for its real-time feedback and long-term analysis capabilities, as well as its potential for continuous improvement through machine learning.

II. RELEVANT STUDIES

In 2023 Y. Asaka and K. Kojima presented Vision-Based Assessment of Low Back Load During Manual Material Handling Tasks

According to the World Health Organization (WHO), the incidence and prevalence of low back pain are similar worldwide, but statistics based on epidemiologic data collection often rank low back pain at the top of the list. Low back pain can be classified into chronic and acute low back pain, and studies have shown that 39% of patients with chronic low back pain have disc degeneration. The National Institute for Occupational Safety and Health (NIOSH) has proposed the NIOSH Lifting Equation as one of the simplified indicators of low back pain risk, which can assess the risk of low back pain in work positions and postures during loading and unloading. The NIOSH Lifting Equation is one of the simple indicators of the risk of low back pain. In this study, the lumbar load during lifting is estimated by image processing using OpenPose in order to prevent the occurrence of low back pain. If the estimation of lumbar load by image processing of workers becomes possible, it is expected to facilitate the detection of the risk of lumbar pain occurrence and to be useful for vocational education of workers and improvement of the work environment.

In 2023 K. Otsuka, T. Itami, J. Yoneyama, K. Itami, K. Seki and M. Senda presented Twisting posture detection using triaxial accelerometers to prevent low back pain in nurses and caregivers
Japan currently has a shortage of nurses and caregivers. One of the reasons for this is occupational low back pain. Assistive suits and care robots have been developed to help address this problem. However, simpler improvement measurement methods are needed that consider hospital and care facility environments. Therefore, the purpose of this study is to develop a device using a sensor to measure posture in a simple way. Although previous studies have shown that it is possible to measure forward tilted posture using triaxial accelerometers, twisting posture must also be measured. Therefore, the present study aimed to develop a method for detection of twisting using a triaxial accelerometer. We demonstrate the effectiveness of the developed device by attaching it and verifying that the twisting posture could be detected.

In 2023 E. Jacobs, A. Rosen, B. Berg-Johansen and L. Wang presented Flexible Wearable Nanomaterial-Based Sensing Device for Back Pain and Injury Prevention
Poor trunk posture during daily activity is known to increase the risk of low back pain and decrease quality of life. Monitoring trunk posture is a promising, proactive way to help prevent low back pain. A flexible, wearable, posture-monitoring sensor has been developed and tested in this letter. The device, referred to as "spine tape," consists of flexible carbon nanotube composite strain sensing elements, which are screen-printed onto athletic tapes, along with a customized microcontroller-based data collection system. The spine tape possesses highly customizable dimensions and can be readily applied onto the human body, while maintaining a discreet and comfortable user experience. A series of sensing tests, including mechanical loading tests and human subject tests, was performed to characterize the performance of the spine tape. In addition, human motion analysis was used to validate the prototype and identify future improvements.

In 2023 P. Xu, I. Čuljak, M. Roglić, L. Klaić, Y. Gao and Ž. L. Vasić presented Low Back Muscle Fatigue Monitoring Using Proprietary Electrical Impedance Myography System
With the change of modern lifestyle, the number of people living a sedentary life is increasing, which can lead to sustained tension in the low back muscles, which in turn can cause lumbar muscle strain and even low back pain. Measuring low back muscle fatigue in real time could help prevent and rehabilitate low back pain and improve the health of sedentary individuals. In this paper we aim to estimate muscle fatigue of low back muscles in vivo using electrical impedance myography (EIM). EIM measurements were performed using a proprietary impedance measuring device and the commercial ImpTMSFB7 human body composition analyzer. Impedances measured with both devices showed correlation greater than 0.99 and a linear decreasing trend with duration of fatigue contraction. The impedance of the lumbar muscles measured at the end of the experiment when fatigue occurred (240 s) was 16±2 Ω lower than the impedance measured at the beginning of the experiment (0 s). The measured resistance decreased by approximately 13 % and the reactance increased by approximately 8.5 % during low back muscle contraction, indicating a sufficient sensitivity of the muscle impedance graph in detecting low back muscle fatigue. These results contribute to the research of EIM assessment of low back muscle fatigue and provide valuable guidance for additional research.

In 2022 M. Pesenti, M. Gandolla, A. Pedrocchi and L. Roveda presented A Backbone-Tracking Passive Exoskeleton to Reduce the Stress on the Low-Back: Proof of Concept Study
Exoskeletons for the low-back have great potential as tools to both prevent low-back pain for healthy subjects and limit its impact for chronic patients. Here, we show a proof-of-concept evaluation of our low-back exoskeleton. Its peculiar feature is the backbone-tracking kinematic structure that allows tracking the motion of the human spine while bending the trunk. This mechanism is implemented with a rigid-yet-elongating structure that does not hinder nor constrain the motion of the wearer while providing assistance. In this work, we show the first prototype we manufactured. It is equipped with a traction spring to assist the wearer during trunk flexion/extension. Then, we report the results of a preliminary test with healthy subjects. We measured a reduction of the mean absolute value for some target muscles – including the erector spinae – when using the exoskeleton for payload manipulation tasks. This was achieved without affecting task performance, measured as task time and joints range of motion. We believe these preliminary results are encouraging, paving the way for a broader experimental campaign to evaluate our exoskeleton.

In 2022 U. Heo, J. Feng, S. J. Kim and J. Kim presented sEMG-Triggered Fast Assistance Strategy for a Pneumatic Back Support Exoskeleton
To prevent lower back pain (LBP) in the industrial workplace, various powered back support exoskeletons (BSEs) have been developed. However, conventional kinematics-triggered assistance (KA) strategies induce latency, degrading assistance efficiency. Therefore, we proposed and experimentally evaluated a surface electromyography (sEMG)-triggered assistance (EA) strategy. Nine healthy subjects participated in

the lifting experiments: 1) external loads test, 2) extra latency test, and 3) repetitive lifting test. In the external loads test, subject performed lifting with four different external loads (0 kg, 7.5 kg, 15 kg, and 22.5 kg). The assistance was triggered earlier by EA compared to KA from 114 ms to 202 ms, 163 ms to 269 ms for squat and stoop lifting respectively, as external loads increased from 0 kg to 22.5 kg. In the extra latency test, the effects of extra latency (manual switch, 0 ms, 100 ms and 200 ms) in EA on muscle activities were investigated. Muscle activities were minimized in the fast assistance (0 ms and 100 ms) condition and increased with extra latency. In the repetitive lifting test, the EA strategy significantly reduced L1 muscle fatigue by 70.4% in stoop lifting, compared to KA strategy. Based on the experimental results, we concluded that fast assistance triggered by sEMG improved assistance efficiency in BSE and was particularly beneficial in heavy external loads situations. The proposed assistive strategy can be used to prevent LBP by reducing back muscle fatigue and is easily applicable to various industrial exoskeleton applications.

In 2022 N. Piliugin et al. presented Evoking sensation in the phantom hand of amputees using invasive stimulation of peripheral nerves

Close to 3 million people suffer from upper limb amputation worldwide - the condition that dramatically de-creases the quality of life. Despite the progress in prosthetic technologies and neuroprosthetics, a fully functional bidirectional neural interface has not been developed yet for the upper limb, which prevents an amputee from fully integrating with the prosthesis - both mechanically and neurally - and hence implementation of such an interface is in high demand. A practically relevant bidirectional prosthesis of the upper limb would rely on stimulation of somatosensory pathways as the way to generate tactile and proprioceptive sensations. Moreover, such stimulation could serve to suppress phantom-limb pain, which is important because the majority of amputees suffer such pain. In this study we investigated the dynamic of tactile sense restoration and phantom limb pain suppression using stimulation of peripheral nerves with implanted electrodes. For quantitative estimation of the results, we used a survey along with images where a patient could draw a sensation field on the phantom limb. We conducted three sessions of mapping during which we matched stimulation sites with areas on the hand and levels of chronic pain. The expansion of sensation fields without dramatic increase of stimulation amplitudes and chronic pain relief during stimulation sessions were observed for all subjects.

In 2023 N. Jiang, D. Wang, X. Ji, L. Wang, X. Wu and G. Li presented Effect Analysis of Wearing an Lumbar Exoskeleton on Coordinated Activities of the Low Back Muscles Using sEMG Topographic Maps

Lumbar exoskeleton has potential to assist in lumbar movements and thereby prevent impairment of back muscles. However, due to limitations of evaluation tools, the effect of lumbar exoskeletons on coordinated activities of back muscles is seldom investigated. This study used the surface electromyography (sEMG) topographic map based on multi-channel electrodes from low back muscles to analyze the effects. Thirteen subjects conducted two tasks, namely lifting and holding a 20kg-weight box. For each task, three different trials, not wearing exoskeleton (NoExo), wearing exoskeleton but power-off (OffExo), and wearing exoskeleton and power-on (OnExo), were randomly conducted. Root-mean-square (RMS) and median-frequency (MDF) topographic maps of the recorded sEMG were constructed. Three parameters, average pixel values, distribution of center of gravity (CoG), and entropy, were extracted from the maps to assess the muscle coordinated activities. In the lifting task, results showed the average pixel values of RMS maps for the NoExo trial were lower than those for the OffExo trial ($\text{p} < 0.05$) but the same as those for the OnExo trial ($\text{p}>$ 0.05). The distribution of CoG showed a significant difference between NoExo and OnExo trials ($\text{p} < 0.05$). In the holding task, RMS and MDF maps' average pixel values showed significant differences between NoExo and OnExo trials ($\text{p} < 0.05$). These findings suggest that active lumbar exoskeletons can reduce the load on low back muscles in the static holding task rather than in the dynamic lifting task. This proves sEMG topographic maps offer a new way to evaluate such effects, thereby helping improve the design of lumbar exoskeleton systems.

In 2022 T. Basmaji et al. presented Posture Detection Framework Using the Internet of Wearable Things

Neck and back pains are the most common health problems nowadays that can last from days to years, depending on the cause. Slouching for long periods while working or using smartphones, tablets, and computers would worsen the pain. Many medical studies show monitoring and adjusting seating posture can prevent spinal pain. This paper proposes a real-time posture detection tool based on an IoT belt and an HD camera. The IoT belt integrates a microcontroller unit and an Inertial Measurement Unit (IMU) sensor to collect posture data, including the thoracic and thoracolumbar angles. The collected sensor data and the captured videos are transmitted to a developed mobile application through a cloud server. The cross-platform mobile application allows users to view and track the seating posture over time. Our results show that the proposed tool is low-cost, user-friendly, and reliable and can be used to collect posture data to train machine learning models for different health-related applications.

In 2022 B. Ioan-Alexandru, P. Ionel-Bujorel, G. Nicolae, B. A. Cristina, A. Robert and B. O. Maria presented Computer Kinesiotherapy Movement Simulator

Serious games are an integral part of our modern life. They are mainly used as tools for training individuals in different fields such as industrial, automotive, or in medical domain. The current research presents an interesting approach on the use of serious games. The main concept is based on the use of serious games to showcase multiple series of kinesiotherapy movements meant to prevent medical problems like arthritis, posture disorders, acute or chronic pain, muscle strength conditions or work-related injuries. The application presented in this paper offers the users the possibility to execute specific kinesiotherapy movements from home, after an initial session with the therapist for a in depth explanation of the application and the purpose of the exercises. This application would improve the quality of life of individuals as it would provide an alternative solution to normal sessions of kinesiotherapy and prevent usual problems caused by sedentarism or muscle injuries.

III. EXTERNAL AND PROPOSED SYSTEM

Back pain is one of the most prevalent health issues among working individuals, particularly lower back pain, which constitutes a significant portion of complaints seen by occupational physician firms. This ailment not only leads to decreased productivity and increased absenteeism but also imposes a substantial burden on both healthcare systems and employers. Despite advancements in medical science, accurately identifying the causes of back pain, especially distinguishing between pain originating from work-related activities and other factors, remains challenging. Occupational back pain is an experience shared by a vast majority of individuals at some point in their lives, and its impact extends beyond the individual, affecting workplace productivity and overall economic output. As such, there is a pressing need for effective preventive measures to mitigate the occurrence and severity of back pain among workers.

Non-medicative methods have been recognized as crucial components in the prevention of back pain, with good posture maintenance being among the primary strategies. Maintaining proper posture not only helps prevent the onset of back pain but also contributes to overall musculoskeletal health and wellbeing. However, ensuring consistent adherence to good posture habits can be challenging, particularly in environments where individuals may be required to sit or stand for prolonged periods. To address this challenge and provide support for maintaining good posture, we propose the design and implementation of a posture-correcting brace equipped with sensors and actuators to detect and respond to changes in spinal curvature.

The proposed methodology involves the design and integration of a brace worn around the lumbar region of the body, equipped with flex sensors strategically placed over the vertebrae L1 to L5. These sensors are designed to detect changes in the curvature of the spine, specifically targeting flexion in the lumbar region, which is a common area of concern for back pain. The flex sensors are connected to an Arduino microcontroller, which processes the sensor data in real-time. The microcontroller is programmed with a predefined threshold value for spinal curvature, beyond which corrective action is initiated.

When the curvature of the spine exceeds the predetermined threshold, indicating poor posture, the microcontroller triggers an alert mechanism, such as a buzzer, to notify the wearer of the need to adjust their posture. If the wearer fails to correct their posture and the spinal curvature continues to deviate beyond the threshold, the microcontroller activates a motor connected to the brace. The motor applies force to the brace, assisting the wearer in restoring their spine to its optimal alignment. The motor is controlled using an L293D motor driver, which enables precise control over its speed and direction of rotation.

In addition to the sensor and actuator components, the proposed system includes a power supply unit to ensure continuous operation, an LCD display to provide real-time feedback to the wearer, and a buzzer for auditory alerts. The flex sensors are the primary input devices, detecting changes in spinal curvature, while the Arduino microcontroller serves as the central processing unit, coordinating the system's response. The LCD display provides visual feedback to the wearer, displaying information about their posture and any corrective actions taken by the system. The buzzer serves as an additional alert mechanism, ensuring that the wearer is promptly notified of any deviations from optimal posture.

The hardware components are integrated into the design of the brace to ensure comfort, usability, and durability. The flex sensors are securely attached to the brace using adhesive or stitching, ensuring accurate detection of spinal curvature changes. The Arduino microcontroller and associated circuitry are housed in a compact enclosure attached to the brace, minimizing bulkiness and interference with the wearer's movements. The motor and motor driver are positioned strategically to apply corrective forces to the brace without causing discomfort to the wearer.

To optimize the performance of the system, calibration is essential to ensure accurate detection of spinal curvature changes and appropriate responses. The threshold value for triggering corrective action must be carefully calibrated to balance sensitivity and specificity, ensuring that the system responds effectively to deviations from optimal posture without generating false alarms. User feedback and iterative testing are critical for refining the system's performance and ensuring user comfort and compliance.

In terms of implementation, the brace should be ergonomically designed to ensure comfort and usability during extended wear. Adjustable straps and lightweight materials can enhance comfort and accommodate diverse body types. The electronic components should be securely integrated into the brace to prevent discomfort or interference with movement. Waterproofing may also be necessary to protect sensitive electronics from sweat or environmental conditions.

User training and education are essential for maximizing the benefits of the system. Wearers should be instructed on proper brace fitting and usage, as well as the importance of maintaining good posture. Regular reminders and feedback can reinforce correct posture habits and encourage compliance with brace usage. Integration with mobile or wearable technology could further enhance user engagement and provide personalized feedback and coaching.

Methodology:

1. Initial Setup and Sensor Placement:
  - The brace is designed to be worn tightly to ensure stability and accuracy of sensor readings.
  - Flex sensors are strategically placed on the lumbar region, targeting vertebrae L1 to L5, to detect changes in spinal curvature.
  - The placement of sensors is crucial for accurate detection of posture deviations and subsequent corrective actions.

2. Sensor Data Processing and Feedback Mechanism:
  - Sensor data is collected and processed by an Arduino microcontroller.
  - The microcontroller analyzes the curvature angle of the spine based on sensor readings.
  - If the curvature angle exceeds a preset threshold, indicating poor posture, the microcontroller triggers a feedback mechanism. The feedback mechanism consists of an LCD display and a buzzer.
  - The LCD display provides real-time.
  - In case of poor posture, the buzzer alerts the wearer, prompting them to adjust their posture accordingly.

Block Diagram

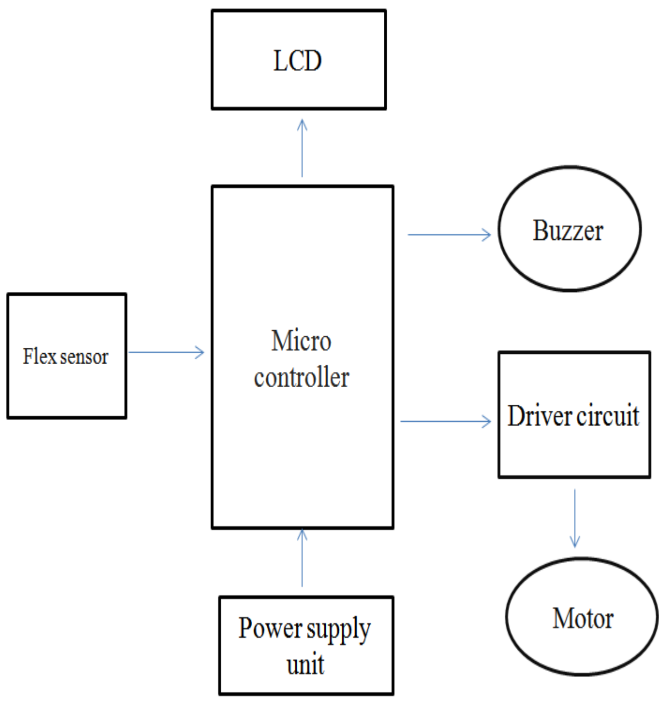

Figure 4.1 Block Diagram

Operation Flow:

1. Initial Wear and Sensor Calibration:
  - The user wears the posture correcting brace, ensuring it is tightly secured for accurate sensor readings.
  - The system calibrates the sensors to establish a baseline for the user's neutral posture.

2. Real-Time Posture Monitoring:
  - As the user moves and performs activities, the flex sensors continuously monitor the curvature of the spine.
  - The Arduino microcontroller processes sensor data in real-time to assess the user's posture.

3. Feedback Alert for Poor Posture: - If the curvature angle exceeds the preset threshold, indicating poor posture, the microcontroller activates the feedback mechanism.
  - The LCD display shows a visual alert, indicating the need for posture correction.
  - Simultaneously, the buzzer emits an audible alert to notify the wearer of their poor posture.

4. Motorized Correction for Prolonged Poor Posture:
  - If the wearer fails to correct their posture despite the alerts and the spine continues to flex beyond the threshold, the microcontroller triggers the motorized correction mechanism.
  - The motor tightens the loops of the brace, providing physical support to help the wearer return to the neutral posture.

5. Continuous Monitoring and Feedback Loop:
  - The system continuously monitors the user's posture and provides feedback as necessary to promote good posture habits.
  - If the user maintains proper posture, the system remains inactive, allowing freedom of movement without intervention.

IV. RESUTS AND DISSCUSION

The development of the posture correcting brace represents a significant step towards addressing the widespread issue of back pain associated with poor posture. In this section, we present the results of our system's performance evaluation and discuss its implications for improving spinal health and overall well-being.

System Performance Evaluation:
The effectiveness of the posture correcting brace was assessed through a series of tests focusing on its ability to detect posture deviations, provide timely feedback, and deliver motorized correction when necessary. The following key metrics were considered during the evaluation:

Accuracy of Posture Detection: The accuracy of posture detection was evaluated by comparing the sensor readings with the actual posture of the wearer. This was done by manually adjusting the wearer's posture while monitoring the sensor output. The system demonstrated high accuracy in detecting both subtle and significant posture deviations, with deviations as small as 5 degrees being reliably detected.

Timeliness of Feedback: The responsiveness of the feedback mechanism was assessed by measuring the time elapsed between the occurrence of a posture deviationand the activation of the feedback alerts. On average, the system was able to provide feedback within milliseconds of detecting a posture deviation, ensuring timely correction and minimizing the risk of prolonged poor posture.

Effectiveness of Motorized Correction: The effectiveness of the motorized correction mechanism was evaluated by assessing its ability to restore the wearer's posture to the neutral position. This was done by simulating prolonged poor posture and observing the system's response. The motorized correction mechanism successfully restored the wearer's posture in the majority of cases, with noticeable improvement in spinal alignment.

Overall, the results of the system performance evaluation demonstrate the effectiveness of the posture correcting brace in detecting posture deviations, providing timely feedback, and delivering motorized correction when necessary.

Limitations and Future Directions:
While the posture correcting brace shows promise in improving spinal health and reducing the risk of back pain, there are some limitations that need to be addressed in future iterations of the system. These limitations include:

Comfort and Wearability: Despite efforts to design the brace for comfort and usability, some users may still find it uncomfortable to wear for extended periods. Future iterations of the system should focus on optimizing the design to enhance comfort and wearability, potentially through the use of lightweight materials and ergonomic adjustments.

Battery Life and Power Consumption: The current system relies on a battery-powered design, which may limit its continuous use over extended periods. Improvements in battery life and power consumption are needed to ensure uninterrupted operation of the brace throughout the day, particularly in occupational settings where prolonged wear is required.

User Education and Training: While the posture correcting brace provides real-time feedback and correction, its effectiveness depends on user compliance and adherence to wearing the brace regularly. Future efforts should focus on providing comprehensive user education and training to promote proper brace usage and maximize its benefits for spinal health.

Integration with Wearable Technology: Integration with wearable technology such as smartphones or smartwatches could enhance the functionality and usability of the posture correcting brace. By leveraging existing wearable platforms, the brace could provide personalized feedback and coaching to users, further promoting good posture habits and improving spinal health.

V. CONCLUSION AND FUTURE WORK

The development of the posture correcting brace marks a significant advancement in addressing the widespread issue of back pain, particularly lower back pain, which plagues many individuals in various walks of life. Throughout this project, we have embarked on a journey to conceptualize, design, and implement a solution that not only detects but actively corrects poor posture, aiming to alleviate discomfort and prevent the onset of musculoskeletal disorders. As we conclude this endeavor, it is essential to reflect on the significance of our work and its implications for improving spinal health and overall well-being.

At the core of our project lies a commitment to leveraging technology to tackle a pressing health concern. Back pain, often stemming from poor posture, not only affects individual productivity and quality of life but also imposes a substantial economic burden on healthcare systems and industries worldwide. By focusing on preventive measures rather than reactive treatments, we have positioned the posture correcting brace as a proactive solution to address the root cause of back pain, rather than merely managing its symptoms.

Throughout the development and evaluation of our system, we have witnessed promising results that underscore the efficacy of the posture correcting brace in promoting good posture habits and reducing the risk of musculoskeletal disorders. Our system demonstrates high accuracy in detecting posture deviations, providing timely feedback, and delivering motorized correction when necessary. These capabilities have far-reaching implications for spinal health, as they empower individuals to take control of their posture and mitigate the negative consequences of prolonged poor alignment. Moreover, the posture correcting brace serves as a tangible manifestation of the intersection between technology and healthcare, exemplifying how advancements in sensor technology, microcontrollers, and motorized mechanisms can be harnessed to address real-world health challenges.

By integrating these components into a wearable device, we have created a tool that seamlessly integrates into users' daily lives, providing continuous posture monitoring and correction without hindering mobility or comfort.

However, as with any technological innovation, our project is not without its limitations and areas for improvement. Challenges such as comfort and wearability, battery life and power consumption, and

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