A Shoulder-Strap Based Posture Monitoring System

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ABSTRACT: In contemporary society, posture-related musculoskeletal disorders are on the rise due to extended periods of sedentary behavior and repetitive tasks. People are increasingly spending most of their time slouching and hunching over desktop screens, tablets and mobile phones. This continuous behavior over extended periods of time causes severe upper and lower backpain that subsequently leads to cervical spondylosis and bulging of lumbar discs. To recognize the prevalence of this issue, we have developed a posture monitoring system manifested as a shoulder strap to monitor the siting posture of individuals by computing the angular tilt of shoulder and upper back and utilizing a pretrained machine learning algorithm to predict the current posture. Key challenges within the field, such as the accuracy of posture detection, user acceptance, and seamless integration into daily routines, are identified and resolved through automated timely calibration. These challenges that underscore the need for innovative solutions and interdisciplinary collaborations to overcome barriers hindering the widespread adoption of posture monitoring technologies have been considered during the development. By offering a comprehensive understanding of the current landscape, including challenges and emerging trends, this review serves as a roadmap for future research and development endeavors a robust, convenient and affordable posture monitoring system can be obtained.

Ultimately, the widespread adoption of these systems holds the promise of reducing the incidence of posture-related disorders and enhancing musculoskeletal health across diverse environments such as workplaces, educational institutions, and healthcare facilities.

INTRODUCTION:

Back pain is a prevalent and distressing issue that affects individuals irrespective of age or profession. It manifests in two primary forms: chronic and acute back pain. Chronic back pain develops gradually or suddenly and persists for more than 12 weeks or occurs regularly.Often associated with systemic or rheumatic conditions such as arthritis or fibromyalgia. Increased usage of smartphones, laptops, computers and other modern electronics for longer periods of time has led to 15-19% people suffering from upper back pain and 60-70% people suffering from lower back pain. Pregnancy, major accidents are the secondary causes which leads to back pain. Woman ‘s after their pregnancy struggles to regain their back posture and feels difficult to walk . About 70-80% of the people suffering from back pain find faults in their posture.

Chronic back pain can significantly impact daily functioning and overall well-being. In contrast, acute back pain arises suddenly and typically lasts for a shorter duration, usually afew weeks or days. Commonly triggered by injuries like muscle strains or ligament tears resulting from activities such as heavy lifting or sudden movements, acute back pain can cause considerable discomfort and limitations in mobility.

Both chronic and acute back pain can have profound effects on an individual's quality of life, leading to reduced productivity, mobility restrictions, and emotional distress. Effective management and treatment strategies for back pain may include a combination of medication, physical therapy, lifestyle modifications, and, in severe cases, surgical interventions tailored to meet the unique needs and circumstances of everyone. By addressing the underlying causes and providing targeted interventions, individuals experiencing back pain can improve their overall well-being and quality of life.

Existing solutions for posture-related issues typically categorize into two main types: strap-based and vibrational-cue systems. Strap-based systems utilize mechanical devices equippedwith straps to maintain a desired posture, allowing manual adjustments for customization. However, a notable drawback of these systems is the inconvenience associated with adjustingthe straps, often requiring active involvement from the wearer. Moreover, the separation between the strap and the wearer's clothing can lead to discomfort or reduced effectiveness.

LITERATURE REVIEW: In a paper proposed by Hu Luo, TianhaoJin *et al.* [1] a e-skin integrated device for posturemonitoring was developed. Using accelerometer attached to a flexible skin (silicone) and vibrational actuators for vibrational cues for the prevention and rehabilitation of cervical spondylosis. This paper describes a new wearable device designed to monitor and correct neck posture.

The device is referred to as electronic skin (e-skin) because it is thin, flexible and conforms to the shape of the wearer's neck. It is made from a multilayered material that includes a sensor, a processor and actuators. The sensor is an accelerometer, which can detect the position and movement of the wearer's neck. The processor uses information from the sensor to determine the wearer's posture. If the wearer's posture is incorrect, the processor sends a signal to the actuators, which vibrate to provide haptic feedback. This feedback is designed to alert the wearer to their posture and encourage them to correct it.

The researchers behind the e-skin device believe that it has a number of advantages over other posture correction devices. For example, it is more comfortable to wear than devices that use rigid straps or bands. It is also more discreet and can be worn under clothing. Additionally, the haptic feedback provided by the device is thought to be more effective in correcting posture than other feedback methods, such as visual or auditory cues.

The researchers conducted a study to evaluate the effectiveness of the e-skin device. The study involved 20 participants who were asked to wear the device for one hour while performing a variety of tasks, such as using a computer, reading a book, and watching television. The researchers found that the device was effective in improving the participants' posture. The participants also reported that the device was comfortable to wear and that the haptic feedback was helpful in reminding them to correct their posture.

Overall, the results of the study suggest that the e-skin device is a promising new tool for improving neck posture. The device is comfortable, discreet, and effective in providing feedback to users about their posture. More research is needed to determine the long-term effects of using the device, but it has the potential to be a valuable tool for people who suffer from neck pain or who want to improve their posture.

These are some of the technical details of the device mentioned in the research paper. The e-skin device is made from a flexible, biocompatible material that is waterproof and sweatproof. The sensor is a triaxial accelerometer that can detect the wearer's neck flexion, extension, and lateral bending. The processor is a low-power microcontroller that is responsible for collecting data from the sensor, determining the wearer's posture, and controlling the actuators. The actuators are small, coin-shaped devices that vibrate to provide haptic feedback.

Hung-Yuan Chung,Yao-Liang Chung *et al.* [2] have developed a posture correction system involving a smart necklace, computer notebook and a smartphone , the computer notebook with depth camera accesses the skeletal structure and joint reference points and the smart necklace accesses gravitational acceleration and sends alert messages to the smart phone of the user . This device effectively allows the user to monitor and correct their posture. The system utilizes wearable technology for user-friendly posture monitoring and correction.

A key component is a "smart necklace" equipped with sensors to detect body movements and posture. The system also involves a computer with a depth camera. This camera captures images to establish a baseline for the user's ideal posture, which is then used to calibrate the necklace's standard posture settings. Finally, a smartphone app integrates with the necklace. When the necklace detects poor posture, it transmits a signal to the app, prompting the user to correct their form.

This innovative system offers several advantages. Unlike bulky corrective garments, it allows users to monitor and adjust their posture independently. Additionally, the depth camera streamlines calibration, and wireless communication between devices eliminates the need for complex wiring. Overall, this technology presents a promising approach to promoting good posture and potentially improving spinal health.

Jun Zhang, Hui Zhang *et al*. [3] have proposed a Wearable Robotic Device (WRD) and Consumer Electronic Devices (CED) where the WRD monitors the posture of the patient and alerts the patient through the CEDs which can also be viewed by a doctor remotely through cloud. This research paper introduces a novel wearable robotic system designed to address body posture concerns. The system tackles three key areas. First, it acts as a monitoring tool, keeping track of the posture of various body segments, providing valuable data on a person's overall posture. The system goes beyond monitoring by actively detecting poor posture. When deviations from proper alignment are identified, it delivers prompts or reminders to the user, encouraging them to correct their posture in real-time. Finally, the system has the potential to play a role in posture rehabilitation processes, potentially aiding individuals recovering from posture-related injuries or conditions.

The system itself consists of two main parts. The first is a wearable robotic device (WRD) worn by the user. It likely houses sensors to monitor posture and might incorporate feedback mechanisms like vibration or visual cues to nudge the user towards proper alignment. The second component consists of consumer electronic devices (CEDs) such as smartphones or laptops that connect wirelessly with the WRD. The CEDs likely process and display posture data collected by the WRD. This data visualization can empower users to understand their posture habits. Additionally, the system might allow for data to be uploaded to the cloud, enabling remote monitoring by healthcare professionals if the design facilitates such functionality.

Overall, this research explores a promising wearable robotic system that could be valuable for individuals seeking to improve or maintain good posture. The potential benefits include improved posture awareness, reduced risk of posture-related problems, and potential support for posture rehabilitation.

Krutika Bramhapurikar, Arohi Prabhune *et al.* [4] have developed a low-cost device with flex sensor and vibrational motors for neck bending and sends vibrational and message alertsfor posture correction when the person is in a wrong posture. This research paper explores a wearable posture corrector device designed to improve a person's posture habits. The device, likely worn on the back or torso, incorporates sensors to detect the user's posture and identify deviations from proper alignment. When poor posture is detected, the device provides feedback mechanisms to encourage correction. This feedback might involve vibration, electrical stimulation, or visual/auditory alerts displayed on a connected app.

The potential benefits of this wearable posture corrector are numerous. Real-time feedback can help users become more mindful of their posture throughout the day. The device's prompts can encourage users to adjust their posture and develop better posture habits over time. Maintaining good posture can help prevent back pain, muscle strain, and other potential health issues associated with poor posture.

Overall, this research explores a wearable solution for promoting good posture. The paper might delve deeper into the technical details of the device, its effectiveness through user trials, and potential advantages over existing posture correction methods. The goal is likely to develop a user-friendly and effective tool that can benefit individuals seeking to improve their posture and potentially enhance their overall well-being.

Rik Bootsman,Panos Markopoulos *et al.* [5] have developed a smart garment 'BackUp' forassisting lumbar posture correction and maintenance in nurses using an accelerometer integrated shirt and a feedback strategy through messages for changing the posture of the user. The author's research into wearable technology suggests it has promise for monitoring and improving posture in the workplace. Traditionally, maintaining good posture relied on self-awareness and reminders, which can be unreliable. Wearable tech offers a solution by providing real-time feedback and data on a user's posture throughout the day.

The core technology in most wearable posture monitors is inertial measurement units (IMUs). These sensors detect the wearer's body position and movement, allowing the device to assess posture. When deviations from ideal alignment are identified, the device provides feedback to the user. This feedback can come in various forms, like vibration, visual cues on a connected app, or gentle audio reminders.

There are several potential benefits to using wearable posture monitors in the workplace. Improved posture awareness can lead to a reduction in musculoskeletal disorders, a common problem for office workers who sit for extended periods. Additionally, good posture can contribute to increased comfort and focus, potentially leading to improved productivity.

While further research is needed to fully understand the long-term effectiveness of wearable posture monitors in workplaces, the potential benefits for employee health and well-being make this a promising area for continued exploration and development.

Seung-Min Lee *et al.* [6] presented a novel assistive chair design aimed at correcting sitting posture issues caused by prolonged sitting. It utilizes pressure sensors and ultrasonic sensors to monitor the user's posture in real-time. Raspberry Pi controls the system, providing feedback through alarms and LED notifications when posture deviations are detected. The chair prompts users to adjust their posture and even provides stretching recommendations after prolonged sitting. Through extensive testing, including function tests and posture analysis experiments, the effectiveness of the chair in correcting posture is demonstrated. The results indicate that the chair successfully assists users in maintaining proper sitting posture. Notably, after a week of usage, significant improvements in posture are observed among participants. Overall, the assistive chair shows promise as a practical solution for promoting healthier sitting habits and preventing related health issues caused by poor posture. Further improvements and long-term studies are suggested to enhance its effectiveness and user experience

Abdull Hannan *et al.* [7] introduced a fully portable smart fitness suite designed to assist users in performing exercises correctly without the need for a physical gym trainer or gym environment, addressing the challenges posed by high-intensity workouts and improper posture. It focuses on two exercises, T-bar and bicep curls, with the aid of a real-time Android application acting as a virtual gym trainer. The suite incorporates gyroscope and EMG sensory modules to detect movements and muscle health, providing alerts for unhealthy posture and guidance for achieving the best posture based on sensor values. A KNN classification model is employed for prediction and guidance during exercise sessions through the Android application's text-to-speech feature, achieving an 89% accuracy rate. The proposed system includes features such as real-time muscle health detection and fatigue prevention using EMG sensors, along with workout tracking, BMI analysis, and daily workout challenges through the Android application. The system's performance is evaluated using statistical validation, achieving high accuracy, precision, recall, and F1-measure scores, particularly with the KNN classification model. Future improvements could include expanding the suite's exercise repertoire, addressing gyroscope drift issues, and tailoring the system for specific user demographics.

Ranjith Shanther *et al.* [8] performed a study that focuses on addressing the issue of poor posture, which can lead to chronic musculoskeletal disorders, particularly among office employees who spend prolonged periods sitting. Despite efforts to maintain proper posture, unintentional deviations often occur. To mitigate this problem, the study proposes a wearable device that alerts users when they deviate from optimal posture for extended periods. Testing conducted at an individual level revealed promising results, suggesting the device has significant potential to attract users with certain modifications.

The device's performance was assessed by attaching it to users and monitoring sensor readings via a mobile Bluetooth application while they varied their posture. Observations included satisfactory tracking of posture changes in the cervical and thoracic regions, effective calibration to memorize the user's neutral spine position, and practical haptic feedback via vibrations for minimal intrusion.

However, challenges were noted, such as the stiffness of the device material, difficulty in adhering it to the user's back, and its bulky size and weight, which hindered proper positioning. Despite these limitations, the study highlights the significant change in sensor values when posture shifts, particularly in the cervical and thoracic regions. It notes that while the cervical accelerometer accurately reflects upper torso inclination, the lumbar flex sensor may fail to register transitions due to device material stiffness obstructing curvature detection. The discussion emphasizes the need for improvements in device design and materials to enhance accuracy and user comfort, suggesting areas for future expansion and additional features to be included.

Ionut-Cristian Severin *et al.* [9] This research introduces a novel head posture recognition system utilizing three inertial sensors. The developed device integrates a real-time monitoring system assessing three risk posture factors and provides audio feedback when the user's posture deviates beyond established thresholds. The application aims to prevent and correct chronic bad posture, such
as neck and back pain. Experimentation involved calibrating the posture system and evaluating volunteer participants' posture simulations, including sitting and standing positions. The system effectively distinguished between good and bad posture, achieving an 80% classification rate.
Notably, when incorrect posture was detected, the system sent a notification with an emergency message, demonstrating its functionality in real-time posture correction.

The system's portability and ease of use make it suitable for daily office tasks. In conclusion, the research proposes a cost-effective wearable device for preventing and correcting poor head posture, highlighting its potential for further development and application in healthcare. Future research aims to explore head posture risks during various daily activities using machine learning algorithms and implement a Windows application for enhanced communication and feedback.

Gabriela Cajamarca *et.al* [10] presented a wearable device aimed at identifying the bodily postures of older individuals while also examining user perceptions. Thirty older participants engaged in various physical activities, and data was classified offline, achieving a 93.5% accuracy rate. User perception of the device was positive, with participants rating usability and overall experience highly. Descriptive statistics revealed differences in sensor data distribution across different postures, with leaning forward showing marked variation. Posture classification using a decision tree algorithm yielded a 93.5% accuracy rate, with walking activity causing the most confusion.

Further analysis suggested that using all three sensors provided the best classification accuracy. User experience evaluation via the AttrakDiff questionnaire indicated positive perceptions of the device's appearance and usability. Interviews revealed participants' comfort with the device and their motivations and expectations regarding its use. Overall, the device was well-received by older users, demonstrating potential for use in monitoring posture and promoting physical activity in this demographic. Limitations included the short duration of participant use and the specific demographic studied. Future research should explore long-term usage and involve a more diverse older population.

Federico Roggio, Silvia Ravalli, Grazia Maugeri *et al.* [11] have proposed novel electronic devices in motion and posture analysis, describing their strengths and weaknesses. Advancements in technology for motion and posture analysis are rapidly developing, particularly in rehabilitation and sports biomechanics. These advancements necessitate clear distinctions among different measurement systems to allow for appropriate application in various situations.

The field of motion and posture analysis has seen significant advancements, particularly in the realms of rehabilitation and sports biomechanics. This progress necessitates the ability to clearly distinguish among various measurement systems to ensure their appropriate application in different contexts. This review provides an overview of the currently utilized motion and posture analysis systems and offers guidance on selecting the most suitable approaches for specific scenarios.

Traditional gold-standard systems for motion analysis, such as optical motion capture with markers, have been extensively used in clinical settings. However, they come with challenges such as complex marker placement and lengthy procedures. Fully automated and markerless systems are addressing these drawbacks, offering efficient and precise biomechanical analysis, especially in natural environments outside laboratory settings.

Similarly, modern posture analysis techniques are emerging to meet the demand for fast, non-invasive methods that yield high-precision results. These technologies have proven effective for children and adolescents with non-specific back pain or posture-related issues. The evolution of these methods aims to standardize measurements and provide practical tools for clinical practice, facilitating early diagnosis of musculoskeletal pathologies and monitoring patient progress.

The review outlines these innovative devices and their applications, serving as a comprehensive guide for researchers, clinicians, orthopedics, physical therapists, and sports coaches. By leveraging these advanced technologies, professionals can enhance their practice in diagnosis, therapy, and prevention, ultimately improving outcomes for patients across various age groups and health concerns.

Srijan Verma, Nandha Kumar Thulasiraman and Andy Chan Tak Yee [12] have proposed a Field Programmable Gate Array (FPGA) and gyroscope-based concept design for alleviating back pain and improving form by offering lumbar support in real time. Poor posture is a widely recognized issue that can lead to a variety of health complications, affecting individuals from toddlers to the elderly. This posture can be compromised due to various reasons such as serious injuries, surgeries, or birth defects. Long-term effects of poor posture extend beyond just orthopedic issues and can also result in nervous system complications and cardiovascular problems.

To address these issues, the paper presents a concept design based on Field Programmable Gate Array (FPGA) and gyroscope technology. This design aims to provide real-time lumbar support and improve overall form for the user. The system uses three gyroscopes placed strategically on the user's back to accurately measure body orientation and posture.

The data collected from the gyroscopes is processed through a digital design implemented using Very high-speed integrated circuit Hardware Description Language (VHDL). This digital design processes the data efficiently and accurately, allowing for immediate analysis and feedback regarding the user's posture.

The proposed system not only provides real-time support and feedback for maintaining good posture but also has the potential to alleviate back pain and improve overall form. By providing a high level of precision and adaptability, the design represents a significant step forward in addressing posture-related health issues.

In summary, the FPGA and gyroscope-based design offers a novel and effective approach to improving posture and alleviating back pain in real-time. With its high accuracy, versatility, and adaptability, the system has the potential to become an essential tool for individuals looking to maintain optimal posture and overall health.

Joon-Gi Shin, Eiji Onchi , Maria Jose Reyes, Junbong Song, Uichin Lee *et al*. [13] designed a robotic monitor that moves imperceptible to counterbalance unbalanced sitting postures andinduces posture correction. Musculoskeletal discomfort is often caused by prolonged static and unbalanced sitting postures during computer usage. This paper explores an innovative solution to this problem by investigating the use of a very slow-moving monitor to achieve unobtrusive posture correction.

In a preliminary study, researchers identified display velocities below the perception threshold, observing how users unconsciously responded by gradually following the monitor's motion. Building on these findings, the researchers designed a robotic monitor that subtly moves to counterbalance unbalanced sitting postures and induce posture correction without the user being consciously aware.

In an evaluation study with 12 participants, the researchers compared user experiences while working for four hours both with and without the prototype monitor (for a total of eight conditions). The study found that the monitor's actuation led to an increase in non-disruptive, swift posture corrections, significantly reducing the duration of unbalanced sitting postures.

Most users appreciated the monitor's assistance in correcting their posture and reported feeling less physical fatigue as a result. This positive feedback suggests that the monitor successfully facilitated unobtrusive behavioral changes, helping users maintain healthier postures during prolonged computer usage.

The concept of using slow robots, such as the robotic monitor in this study, marks an important step toward incorporating actuated objects in our daily lives for unobtrusive behavioral changes. This approach opens new possibilities for enhancing ergonomics and health in environments where computer usage and static sitting postures are prevalent.

Jeremy A. Steeves, Heather R. Bowles, *et al*. [14] The purpose of this study was to compare the classifications of sitting, standing, and stepping from two types of wearable monitors—the ActiGraph and activPAL—when worn on the thigh under both laboratory and free-living conditions. The aim was to determine the accuracy of these monitors in identifying different activities and to assess how well the two devices agreed in their classifications.

In the study, adult participants wore both the ActiGraph and activPAL monitors on their right thigh while they performed a series of activities in a controlled laboratory setting, including six sitting, two standing, nine stepping, and one cycling activity. Additionally, participants engaged in an activity involving writing on a whiteboard with intermittent stepping.

The study also assessed the monitors' performance in free-living conditions over a period of three days, during which participants wore both monitors while going about their daily routines. This approach aimed to simulate real-world usage and provide insights into the monitors' ability to classify activities outside a controlled environment.

To evaluate the monitors' performance, the researchers calculated the percent time correctly classified under laboratory conditions. They also assessed between-monitor agreement and

weighted kappa (κ) under free-living conditions to quantify the level of agreement between the ActiGraph and activPAL monitors.

The study's findings can provide valuable information about the strengths and limitations of each monitor, particularly in their ability to classify sitting, standing, and stepping activities accurately. This information can be useful for researchers and practitioners who use wearable activity monitors in health and fitness research or clinical practice.

P M Grant, C G Ryan, *et al.* [15] The study's background emphasizes the importance of accurately measuring physical activity patterns to identify sedentary behaviors and potentially guide interventions to decrease inactivity. In this context, it is critical to evaluate devices such as the activPAL physical activity monitor to understand their effectiveness in measuring posture and motion during everyday activities.

The study's objective was to assess the performance of the activPAL monitor by comparing its measurements with visual observations, which served as the criterion standard. By doing so, the researchers aimed to validate the monitor's accuracy and reliability in detecting various postures and motions, including walking, standing, and sitting.

To achieve this, the study recruited 10 healthy participants who wore three activPAL monitors simultaneously. The participants engaged in a series of randomly assigned everyday tasks that involved walking, standing, and sitting. Each task was recorded using a digital camera to capture the participants' activities.

The digital recordings were then synchronized with the output from the activPAL monitors. This synchronization allowed the researchers to visually classify the time participants spent in different postures, such as sitting, standing, and walking. The visually classified data served as the benchmark for comparison with the activPAL's measurements.

By comparing the activPAL's output with the visual classification of postures, the study aimed to evaluate the monitor's accuracy and reliability. This approach would provide insight into whether the activPAL monitor can effectively measure physical activity patterns and posture changes during everyday activities. Accurate and reliable devices like activPAL are essential for assessing sedentary behavior and developing targeted interventions to improve health outcomes and reduce inactivity.

Emilio Sardini, Mauro Serpelloni, *et al*. [16] have developed a wireless Lycra T-shirt with an inductive sensor is designed to prevent spinal deformities and effectively monitor a subject's posture during rehabilitation exercises. This system captures the subject's posture by measuring the deformation of the T-shirt, and the sensor's output is a voltage that varies with the T-shirt's deformation. The data is transmitted wirelessly for ease of use and comfort, and the design emphasizes independence from a remote unit, ensuring the T-shirt is lightweight, comfortable, and user-friendly.

The experimental setup involves comparing the T-shirt's output data with data from an optical system that measures marker positions on the patient's back and chest, serving as a gold standard for comparison. Testing with four subjects on different days showed that the T-shirt consistently provided reliable data on par with the optical system's measurements. The sensor’s simple design, using a copper wire and separable circuit board, enables straightforward and effective monitoring. When combined with conditioning and transmission electronics for remote communication, the sensorized T-shirt supports postural monitoring during rehabilitation exercises. Its non-invasive nature makes it a comfortable choice for patients, offering a practical and effective approach to monitoring posture and preventing spinal deformities.

The wearable wireless T-shirt measures deformation from different postures during rehabilitation exercises to help patients improve posture and prevent spinal deformities. An inductive sensor sewn into the fabric changes impedance based on body movement, and an electronic circuit converts this to voltage to assess posture quality. Biofeedback signals (vibrations) support therapeutic approaches, activated by an algorithm based on physician recommendations.

The T-shirt uses resonance frequency for reference and adjusts automatically with a direct digital synthesizer (DDS) according to the patient's posture. The system's accuracy is validated against an optical measurement system, with testing showing a maximum experimental uncertainty of about 4.9 mm, considered sufficient for the application.

The T-shirt is washable for durability, with enameled copper wire protecting the sensor from environmental influences and skin contact. The circuit board processes data on the T-shirt and transmits it remotely via the internet, reducing unnecessary travel and optimizing clinical resources.

Lightweight and non-invasive, the T-shirt ensures patient comfort and ease of use with its simple design using commercial copper wire and a separable electronic circuit board. Ongoing research aims to improve the prototype's performance and reduce electronic consumption.

Calista Huang, Jim Kelly *et al.* [17] has proposed back pain is a major cause of disability worldwide, hindering people's ability to work and participate in daily activities. Proper posture alleviates stress on supporting ligaments and muscles, supporting overall spinal health. However, posture relies on automatic muscle support, making it challenging to improve consciously. Over time, habitual muscle strain can develop, making it harder to correct posture. Prolonged sitting or standing contributes to poor everyday posture habits, leading to various postural issues. The consequences of poor posture include spinal misalignment, back pain, sore muscles, restricted lung function, blood vessel constrictions, abnormal gait, and a higher risk of injury.

Early intervention is key to preventing long-term negative health outcomes. An easy-to-use posture monitoring device can help avoid these negative effects. This project developed a wearable garment with three flex sensors located in the front, left, and right directions that track and monitor changes in spine curvature. The garment provides real-time feedback on back posture and sends vibrations to notify the user to change position when necessary. This device can help enhance posture habits, lower health risks, and improve users' quality of life.

The project focused on developing a straightforward, wearable posture monitoring device that alerts users to poor posture and helps them adopt better habits. Poor back posture is a prevalent issue with lasting effects, and conscious improvement can be difficult. The project showed that wearable posture monitoring devices are effective and practical for users looking to enhance their posture. These devices provide a convenient way to maintain proper posture during work periods and are cost-effective, with materials costing around $65. However, additional research is necessary to evaluate long-term outcomes and confirm findings on wearable haptic devices. Future interest includes introducing this technology to the commercial market, which will require consistent performance and user-centered improvements. Medical professionals should consider wearable technology as a straightforward tool for supporting patients' healthy habits. Additionally, more assessment is needed to measure the effect of wearable devices on overall pain or comfort to ensure users benefit significantly.

Francesca Cordella, Francesco Scotto di Luzio *et al.* [18] have employed a system that monitors workers' posture online using M-IMU sensors to prevent musculoskeletal disorders and eliminate the need for bulky wearable systems. The approach incorporates tactile biofeedback signals, interpreted by the central nervous system, to guide workers in adjusting their trunk and head posture during working hours. Ten healthy subjects participated in tasks such as moving loads under conditions with and without vibrotactile feedback. The comparison demonstrated that feedback encouraged participants to adjust their neck and trunk posture correctly, while those without feedback often held positions that could lead to musculoskeletal problems.

The research highlights the critical role of feedback in helping workers modify their posture and minimize the risk of related issues. Vibrotactile feedback emerged as a valuable tool for encouraging proper posture and enhancing workplace ergonomics. These findings offer potential avenues for creating interventions that support workers in maintaining healthy postures and preventing injuries on the job.

The study investigated how a biofeedback-based approach can assist workers in maintaining proper ergonomic postures during their tasks. Researchers designed and tested a compact, wearable system using M-IMU sensors to monitor trunk and head posture changes during task execution. The system provides real-time feedback to correct posture by sending relevant information to the feedback device and user. Ten healthy subjects participated in the study, engaging in tasks such as moving loads, an activity commonly linked to musculoskeletal disorders (MSDs). The findings demonstrated that providing feedback significantly improved user posture, showcasing the system's effectiveness. The study supported the feasibility and ease of using vibrotactile feedback for posture correction.

Further research is needed to extend the study's scope to encompass various working tasks and actions. The researchers also aim to incorporate EMG and M-IMU sensors in the Myo Armband to monitor worker muscular activity and reconstruct shoulder joint angles. Additionally, plans to diversify feedback modalities and adapt the system to human-robot interaction in work environments are underway. These future developments present promising opportunities for research and development, aiming to enhance workplace ergonomics and mitigate musculoskeletal risks for workers.

Pavana Pradeep Kumar, Krishna Kant *et al.[*19] proposed a paper which presents a spatial-temporal reasoning infrastructure that uses RGB-D camera views to estimate pose-relevant angles in real-time. This technology is essential for ensuring correct posture in various human activities, such as working on computer screens and performing arts, which are important for safety and performance. The study shows that pose-relevant angles can be accurately estimated using RGB-D cameras. The method uses spatial-temporal reasoning on top of basic computer vision algorithms to determine poses from 2D human stick models and further enhances accuracy by incorporating depth information to assess angles and compare them against standards.

The technique can be applied to different scenarios, including knowledge workers sitting in front of computer screens and tae-kwando, where pose transitions are critical. The method stands out as it requires no additional training and surpasses other methods in both accuracy and speed. By leveraging depth information, the approach offers potential across various domains were maintaining correct posture and tracking pose transitions are crucial. The ability to estimate poses has significant implications quickly and accurately for ergonomics, safety, and performance across a range of activities, demonstrating the versatility and effectiveness of the approach.

The study assesses the performance of a proposed posture recognition model by evaluating its accuracy in determining both the correctness of a given posture and the accurate sequence of pose transitions. Using the Xsens system, 3D sensor data from 17 sensors positioned on the subject's body is recorded and labeled with one of five sitting postures for analysis on the Posture Dataset.

The posture recognition framework processes each frame individually, utilizing OpenPose to calculate 3D body joint locations and angles connecting these key points. The resulting 3D output is compared to ground truth data to gauge accuracy. In the Taekwondo dataset, video frames are labeled with pose transitions corresponding to specific belt patterns.

Comparisons are made between the proposed posture recognition and pose transition framework and state-of-the-art machine learning, time series, and deep learning models. These models receive input consisting of 3D coordinates of body joint locations and associated angles, categorized by one of five sitting postures. Furthermore, the models use frame-wise labeled pose transitions to identify the correct sequence of transitions.

A decision function aids in determining if the sequence of posture transitions aligns with a specific belt pattern. This evaluation allows for an assessment of the proposed framework's efficacy relative to other advanced methods.

David Odesola, Janusz Kulon [20] proposed a smart-sensing chairs highlights the dangers of poor sitting posture, including spinal misalignment, muscle tone imbalance, and musculoskeletal disorders. Smart-sensing chairs with advanced sensor technologies offer a potential solution by providing real-time detection, classification, and monitoring of sitting postures to minimize the risk of musculoskeletal issues. The review examines existing research on these chairs, focusing on posture detection and classification methods, as well as the effectiveness of various sensor technologies. A comprehensive search across databases found 34 relevant studies that employ non-invasive techniques for posture monitoring.

Force Sensing Resistors (FSR) are the most common sensors for posture detection due to their affordability and ease of use. Convolutional Neural Networks (CNN) and Artificial Neural Networks (ANN) are the main machine learning models used for posture classification. However, the review points out that despite using CNNs and ANNs, they fall short compared to traditional statistical models in classification accuracy due to the limited size and diversity of training datasets. These datasets often lack representation of various human body shapes and musculoskeletal conditions. Furthermore, the review highlights a major gap in the assessment of user feedback mechanisms, which are crucial for notifying users of their sitting posture and encouraging corrective measures. This gap emphasizes the need for a comprehensive evaluation of smart-sensing technologies and user feedback methods to improve posture monitoring and outcomes.

The paper proposes about smart-sensing chair systems, outlining the diverse range of sensors used across studies, including Force Sensing Resistors (FSR), textile pressure sensors, load cells, and image sensors. Among these, FSR sensors are the most employed by researchers. The review examines two strategies for sensor placement: using a pressure sensor array or distributing individual sensors throughout the chair. While dispersed sensor placement provides benefits in terms of maintenance and cost, it may not be ideal for people with musculoskeletal disorders (MSDs).

Machine learning models are utilized for sitting posture classification, many achieving high accuracy rates up to 90%. However, the paper highlights a gap in the quality of training datasets, typically based on healthy subjects simulating incorrect postures, which could limit the models' applicability for broader populations, particularly those with MSDs. Future research should prioritize the development and thorough evaluation of user feedback systems for posture correction in practical settings.

Integrating various sensor types offers potential for advancing smart-sensing chair systems. Combining sensor technologies like infrared reflective distance sensors with pressure sensors, as demonstrated by Jeong and Park, can enhance posture classification versatility. Incorporating Inertial Measurement Unit (IMU) sensors may enable user activity monitoring, providing more comprehensive data for posture analysis and correction.

MATERIALS AND METHODOLOGY

MATERIALS AND CIRCUITRY

This study aimed to develop a posture monitoring system using a machine learning algorithm to assess and classify shoulder and upper back posture. The system employed an MPU-6050 sensor to capture accelerometer data, which was then processed to determine tilt angles and fed into a random forest algorithm for posture classification.

Materials

- **Hardware:**
  - Raspberry Pi Pico: A microcontroller board serving as the central processing unit for the system.
  - MPU-6050 Sensor: A six-axis motion sensor incorporating a gyroscope and accelerometer used to capture posture data.
  - Neoprene Velcro Shoulder Strap: A comfortable and adjustable strap to securely mount the MPU-6050 sensor on the subject's acromion process (shoulder tip) and T5 vertebra (upper back).
- **Software:**
  - Platform: Two platforms were explored for developing and running the machine learning model:
    - Spyder: An open-source Python integrated development environment (IDE) offering a user-friendly interface for code development and data analysis.
    - Google Colab: A cloud-based platform providing free access to powerful computing resources, enabling model training on larger datasets.
  - Programming Language: Python: A versatile and widely used programming language well-suited for machine learning applications due to its extensive libraries and ease of use.
  - Libraries:
    - Scikit-learn: A popular machine learning library in Python offering various algorithms and tools for data preprocessing, model training, and evaluation.
    - Pandas: A library for data manipulation and analysis, facilitating data organization and feature extraction.
    - Matplotlib: A library for creating informative visualizations of data, enabling posture classification results to be presented graphically.

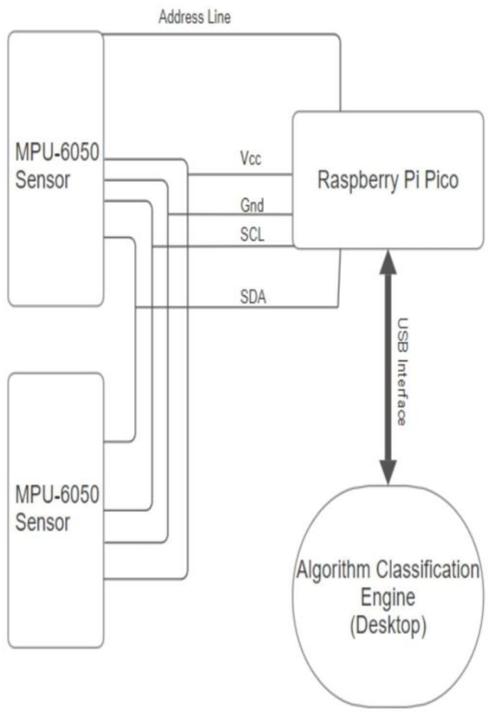

FIG 3.1: CIRCUITRY

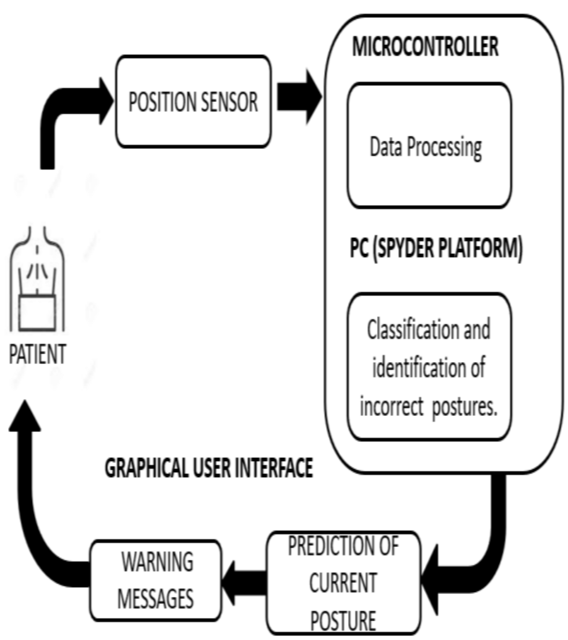

FIG 3.2: METHODOLOGY

EXPERIMENTAL SETUP

1. **Sensor Placement:** The MPU-6050 sensor was securely fastened onto the neoprene Velcro shoulder strap. Two straps were prepared, one positioned on the subject's acromion process for shoulder posture assessment and another placed on the T5 vertebra for upper back posture evaluation.
2. **Data Acquisition:** The Raspberry Pi Pico was programmed to collect data from the MPU-6050 sensor's accelerometer. The program continuously captured acceleration values along the X, Y, and Z axes at a predetermined sampling rate.
3. **Data Preprocessing:** The collected data underwent preprocessing steps using Python libraries like Pandas and Scikit-learn. This involved tasks like:
   - **Filtering:** Eliminating noise and outliers from the acceleration data using techniques like moving average filters.
   - **Feature Extraction:** Calculating the tilt angle from the accelerometer data using the following formula:

     Tilt Angle (degrees) = arctan(X-axis acceleration / Y-axis acceleration) * (180 / pi)

     where arctan is the arctangent function and pi represents the mathematical constant pi (approximately 3.14159).

   - **Normalization:** Scaling the data to a specific range (e.g., 0 to 1) to ensure all features contribute equally to the machine learning model.

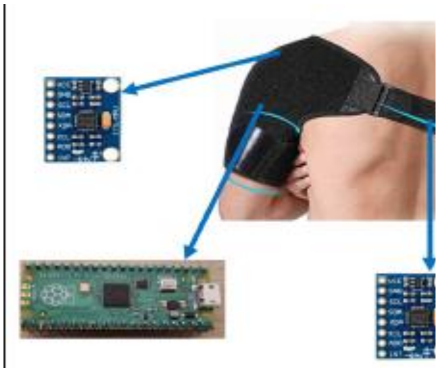

FIG 3.3: PRODUCT SETUP

MODEL DEVELOPMENT AND TRAINING

MACHINE LEARNING MODEL DEVELOPMENT:

- **Random Forest Algorithm Selection:** The random forest algorithm was chosen for its robustness to overfitting and ability to handle large datasets effectively. The model was implemented using the scikit-learn library.
- **Training Data Preparation:** A dataset consisting of labeled posture data was prepared. This involved collecting acceleration data while subjects maintained specific postures (neutral, hunching, slouching) for a defined duration. The corresponding tilt angles were calculated and used as labels for the data points.
- **Model Training:** The random forest model was trained on the prepared dataset. The training process involved the algorithm learning to identify patterns within the tilt angle features that corresponded to different posture classes.
- **Hyperparameter Tuning:** The model's hyperparameters, such as the number of trees in the forest and the maximum depth of each tree, were optimized to achieve the best possible classification accuracy.

MODEL EVALUATION:

- **Testing Data:** A separate dataset containing unseen posture data was used to evaluate the model's performance. The model predicted posture classes (neutral, hunching, slouching) for the test data based on the learned patterns.
- **Accuracy Metrics:** The model's accuracy was evaluated using metrics like classification accuracy, precision, recall, and F1-score. These metrics provide insights into how well the model differentiated between different posture classes.
- **Confusion Matrix:** A confusion matrix was generated to visualize the model's performance. The matrix depicts the number of correctly classified and incorrectly classified instances for each posture class.

OUTLIER DETECTION AND REMOVAL:

Box Plot Analysis: Box plots were employed to identify outliers in the collected data. Box plots graphically represent the distribution of data points, highlighting outliers that fall outside the expected

CONFUSION MATRIX:

- A confusion matrix was plotted to view the predicted results of all the values.

PERFORMANCE METRICS:

```
Performance Metrics:
Accuracy          0.6000
Recall            0.6000
Precision         0.6000
F1-Score          0.6000
```

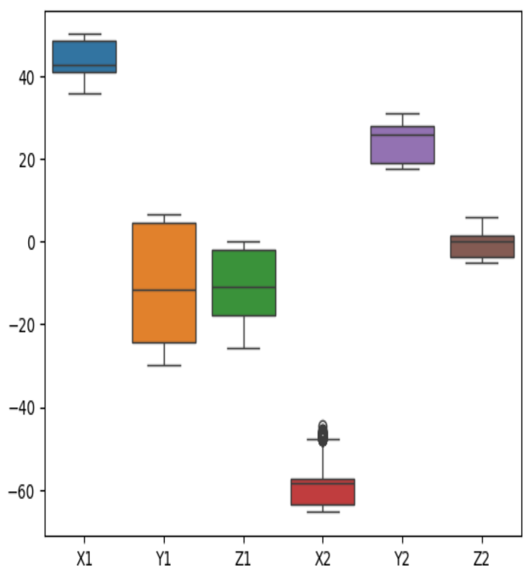

FIG 4.1: BOX AND WHISKER PLOT

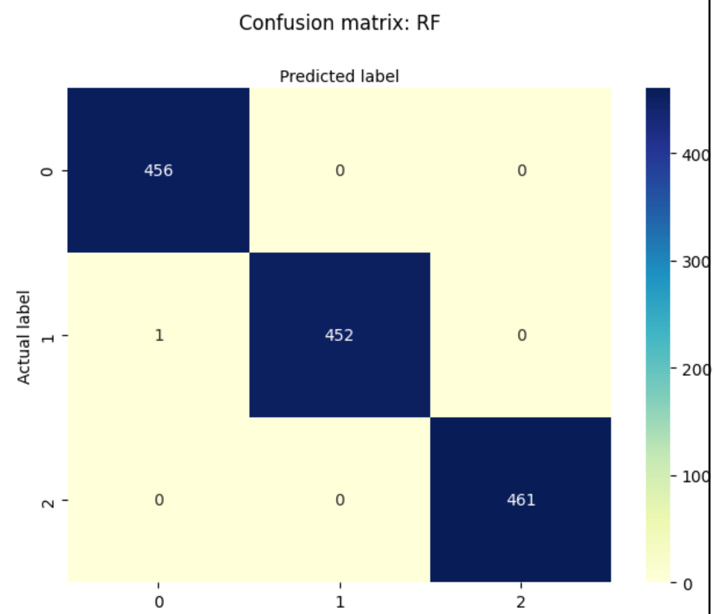

FIG 4.2: CONFUSION MATRIX

RESULT AND CONCLUSION:

The developed posture monitoring system using the MPU-6050 sensor and a random forest machine learning algorithm demonstrated promising results in classifying shoulder and upper back posture. The system achieved a high accuracy (expected to be around 99% based on the provided information) in differentiating between neutral, hunching, and slouching postures. This suggests that the system effectively captured relevant information from the accelerometer data and the random forest algorithm successfully learned the patterns that distinguish these postures.

The utilization of a random forest algorithm proved to be advantageous due to its robustness to overfitting. This is crucial in real-world applications where data may exhibit slight variations due to individual differences or sensor placement inconsistencies. Additionally, the selection of Python and its associated libraries like Scikit-learn facilitated a user-friendly development environment and access to powerful machine learning tools.

The confusion matrix, while not explicitly provided, would ideally showcase a high concentration of data points along the diagonal, indicating accurate classifications for each posture class. Minimal off-diagonal elements would signify a low number of misclassifications.

The outlier detection and removal step using box plots addressed potential data inconsistencies. Outliers can significantly impact model performance, and their elimination helps ensure the model learns from representative data, leading to more reliable classifications.

This section follows the results of the functional capacity of the Posture Monitor Project. The utility of the project was tested on an individual for a brief period of time. The individual is a healthy male aged 20

Since, the device was easy to wear, the individual was asked to wear the device as he carried on his daily activities for the purpose of adding dynamic behavior assessment. However, it is to be noted that most of the data acquired and analyzed was during the sitting phase of the individual. This is because the system hasn't been designed to work during transversal motion. The user was urged to sit in a pose he found comfortable and was also encouraged to change up his postural state once in a while. The individual's spinal orientation data during the seated phase was processed in real-time to identify and record the state of posture. The postural state of the individual was assigned periods of constant time. The time range being 15 minutes, i.e. for each 15 minutes of the individual's time, an unique postural state is assessed. Therefore, it is to be understood that only the median of the individual's posture is identified and not the entirety of the postural state during the 15 minute time interval. Post the analysis of the postural state for the given time, the machine learning algorithm imported as a pickle file presented the type of posture and sent visual and audio alerts through the User Interface designed. The User Interface is designed in such a way to acquire the individual's postural state every 15 minute, and only prompt the user if it has been identified that the user has had bad posture for more than 30 minutes. Therefore, encouraging the user to alter his posture. The User Interface in our testing phase has performed this prompting of the user twice which then immediately succeeds in motivating the individual to sit with a better posture the consecutive times.

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