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Research Article

SPINE WELLNESS MONITORING SYSTEM

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ABSTRACT

One of the most prevalent health issues afflicting a substantial portion of the population is lumbar spine misalignment, a condition that often leads to disc degeneration and painful lower back problems. To address this widespread concern, a groundbreaking wearable device has been introduced, serving as a real-time monitoring system integrated with various imaging modalities. This wearable device incorporates sensors that continuously monitor the body, offering immediate insights into alignment and misalignment issues. It not only collects data but also provides valuable recommendations for addressing these problems, actively assisting individuals in resolving their discomfort. The collected data is securely stored in the cloud, enabling regular tracking and analysis. The cloud-based storage system plays a crucial role in maintaining a comprehensive record of an individual's alignment data, which is periodically displayed. This data repository also facilitates the generation of insightful reports by analyzing the information, thereby enhancing understanding and management of alignment issues. Furthermore, the device goes a step further by offering personalized dietary and exercise recommendations based on the specific problem, aiming to proactively address the root causes of lumbar misalignment and alleviate lower back pain. In essence, this innovative wearable device not only identifies and records alignment issues but also acts as a supportive tool by providing actionable insights and tailored guidance, ultimately contributing to a healthier and pain-free lifestyle.

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INTRODUCTION

Spinal misalignment is a serious issue that affects many people, and it can occur due to the differences in geometrical structure among individuals. While every human body has a similar shape, the geometrical structures are different, which can eventually lead to spinal misalignment. One of the major causes of spinal misalignment is the accumulation of belly fat in the body, which pinches the disc between two vertebrae and causes disc degeneration through creep loading. Creep loading is a gradual increase in stress over time, and it varies by material, so it can also affect human bone, including cortical bone and cancellous bone. As a result of disc degeneration, the body suffers pain, but the symptoms occur slowly over time, which makes it difficult for individuals to be aware of their bodies. Diagnostic options include X-rays, CT scans, and MRI scans, but they are only used once the illness has occurred. Unfortunately, there is no current solution for a real-time monitoring system to improve and solve the problem. Therefore, it is crucial to maintain a healthy lifestyle and manage belly fat to prevent spinal misalignment and related health issues.

In biomechanics, spinal misalignment is studied as an objective issue that can affect the functionality and health of the spine. Spinal misalignments can alter the normal biomechanics of the spine, leading to abnormal movement patterns, increased stress on spinal structures, and reduced function. These changes can cause pain, discomfort, and other health issues that can affect the overall quality of life. Through objective evaluation and analysis, healthcare professionals can identify spinal misalignments and develop treatment plans that aim to restore proper biomechanics and function to the spine. This may involve chiropractic adjustments, physical therapy, corrective exercises, and other interventions aimed at improving spinal alignment and reducing the risk of further injury or degeneration.

The range of motions of the lumbar spine includes flexion, extension, lateral bending, and axial rotation. Each motion has a corresponding angle of movement:

- Flexion: The angle between the upper body and the legs narrows when the spine bends forward. The lumbar spine can flex between 40 and 60 degrees normally.
- Extension: The angle between the trunk and the thighs increases as the spine bends backward. The lumbar spine can extend normally between 20 and 35 degrees.
- Lateral bending: This happens when the spine curves to one side, causing the angle between the upper body and legs to change from one side to the other.

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The lumbar spine can bend to the side normally between 20 and 30 degrees.

- Axial rotation: The spine rotates around its own axis when this happens, with the top moving in one direction and the bottom moving in the opposite direction. The lumbar spine can rotate axially within a normal range of 3 to 18 degrees.

Accidents happen to the spinal cord when the range of motion goes beyond these numbers above mentioned. In addition, not only accidents misalign the spine but also the fat percentage present in body also leads to misalignment in spinal cord. Most of the fat accumulates near the tummy region.This accumulated fat contributes to the creep strain on the spinal cord. This creep also causes many injuries to the spinal cord by misaligning the organs, herniating disc, etc.

A slipped disc, also known as a herniated or ruptured disc, can be caused by a variety of factors, including age-related degeneration, injury, or repetitive stress on the spinal discs, such as from creep loading. Creep loading can cause gradual damage to the spinal discs over time, which may eventually lead to a slipped disc.

The development of a slipped disc in the lumbar spine due to creep loading can be understood in terms of the three stages of creep loading:

1. Viscoelastic deformation: The viscoelastic properties of the spinal disc allow it to deform under a constant load, such as that caused by prolonged sitting or standing. This deformation can cause the disc to bulge outwards, putting pressure on the surrounding tissues and nerves.
2. Plastic deformation: If the load is sustained for an extended period, the disc may undergo plastic deformation, meaning that it will deform permanently and will not return to its original shape. This can cause further pressure on the surrounding tissues and nerves and may lead to a herniation or rupture of the disc.
3. Rupture or herniation: If the load is excessive or applied too quickly, the disc may rupture or herniate, causing the gel-like center of the disc to leak out and putting significant pressure on the surrounding tissues and nerves. This can cause severe pain, numbness, or weakness in the lower back, legs, and feet.

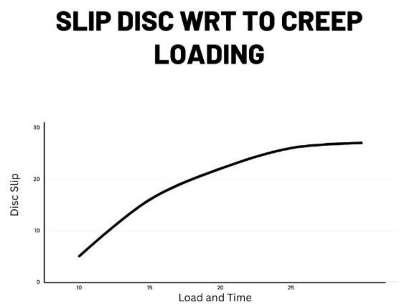

Fig.1 Effect of creep loading on spinal disc

In summary, a slipped disc in the lumbar spine due to creep loading can occur gradually over time, starting with viscoelastic deformation of the disc and progressing to plastic deformation and eventual herniation or rupture. It is important to take steps to reduce the amount of stress on the spine, such as maintaining good posture and taking frequent breaks from sitting or standing, to minimize the risk of a slipped disc due to creep loading. If you experience symptoms of a slipped disc, it is important to seek medical attention promptly to prevent further damage and to receive appropriate treatment.

Accumulation of belly fat in the body can contribute to lumbar spinal misalignment. When tummy fat builds up, it can apply pressure on the spinal discs located between two vertebrae, causing them to degenerate over time. This is due to the principle of creep loading, where long-term stress causes strain to build up in the disc, leading to deformation that can eventually result in spinal misalignment. As the vertebrae become pinched, the disc between them can become compressed and lead to pain and discomfort. Therefore, maintaining a healthy weight and reducing belly fat can help prevent spinal misalignment and related health issues.

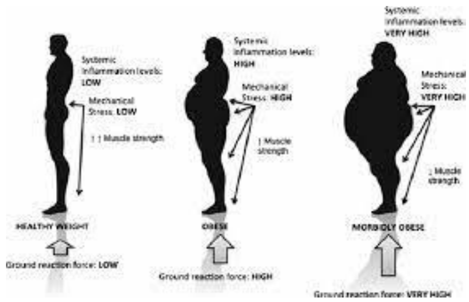

Fig.2 Back of people with different tummy fat accumulated. REF [8]

Biomedical wearable technologies offer a convenient and cost-effective way of monitoring health and managing medical conditions from anywhere, at any time. These technologies are designed to provide personalized healthcare and eliminate the need for advanced healthcare facilities or skilled healthcare professionals. With the use of wearable devices, individuals can track vital signs, physical activity, and other health-related parameters, allowing them to make informed decisions about their health and well-being. This technology has the potential to revolutionize healthcare, making it more accessible and affordable for everyone.

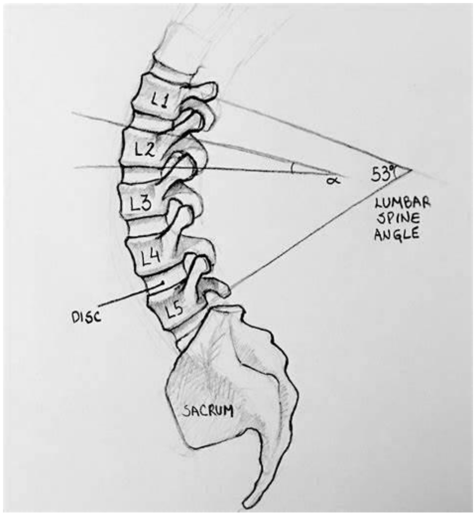

Fig. 3 Misalignment of lumbar spine

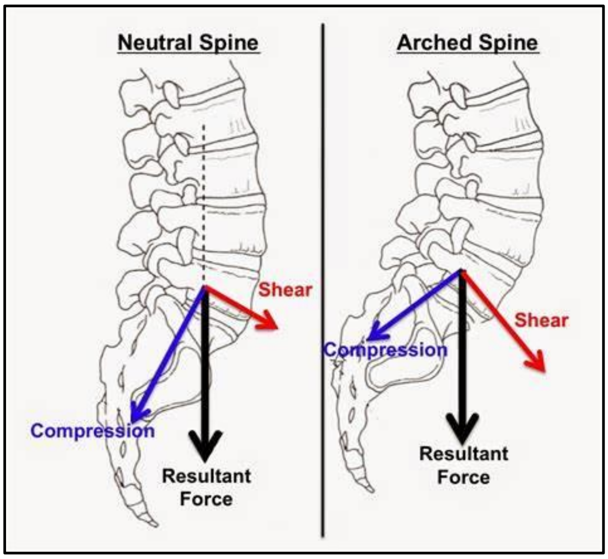

Fig.4 Lumbar spine angles

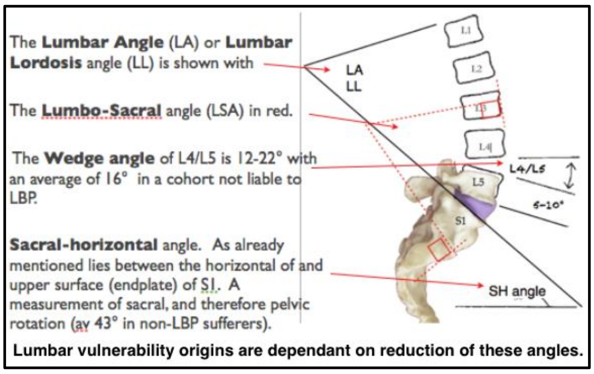

Fig. 5 Biomechanics of Lumbar spinal region

A. Selection of Sensors

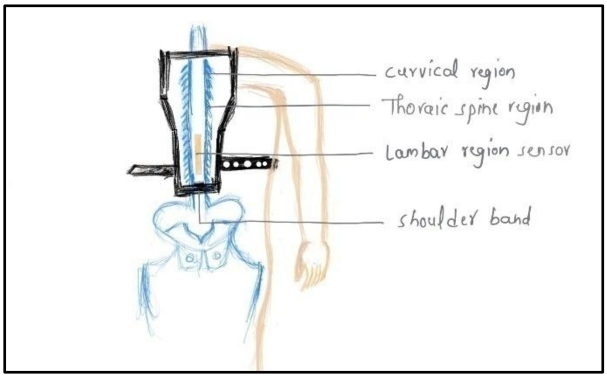

Fig.6 Sensor placement on spine band

Sensor selection is a crucial part of the solution and depends on accuracy and compatibility. Flex sensors are integrated into the spine brace band in the lumbar region of the spine. Sensors act as resistors and resist power applied to them as an input. Flex sensors operate based on bending to resist power and offer superior functionality for today's lifestyle, although some may be difficult to handleFig5.The ideation stage of Spine Wellness SystemMost bend sensors made of conductive ink currently available are unipolar, which means that resistance rises when deflection rises in one direction but stays constant in the other. if twisted the opposite way and the controllers are used The UNO Wi-Fi R3 AtMega328p + NodeMCU is a board that includes an inbuilt ESP8266 8mb memory USB-TTL CH340G compatible with Arduino UNO.

LITERATURE SURVEY

Summarized here is the literature survey on spine wellness System collected from various research papers and journals. There are cases for this explained in depth by many professors and students from different regions of the globe.

According **to Sheikh M. A. Iqbal, Imadeldin Mahgoub, E Du, Mary Ann Leavitt , Waseem Asghar from article no: 9 (2021) pu**blished through npj flexible electronics, wearable devices has laid their path of functionality from detecting the walking steps to identifying the diseases in the human body with the help of modern technology toes offer a wide range of uses in healthcare, from physiological ailments like heart disease, hypertension, and muscular problems to neurocognitive disorders like Parkinson's disease, Alzheimer's disease, and other psychological illnesses. Wearables have recently demonstrated promising advancements as a medicine delivery mechanism, improving their utility in personalized healthcare.

AndreaAliverti has explained the role of wearable devices in biomedical field that are related to the internal functioning. Here the ideation in the wearable devices have changed the method of health check up from a time taking process for results interpretation to getting the results on your finger touch through our smartphones. The biomedical wearable devices are now helping us to monitor the respiratory function of a patient. The biomedical wearable devices also now checking the oxygen intake level through oximeters through sending two wavelengths into skin raging from 660nm (red) to 940nm (infrared) through measuring light absorption depending on the oxygenated and deoxygenated blood levels.

Min Wu, PhD and Jake Luo, PhD has published an article on wearable devices in the biomedical sector stating that wearable devices are enabling their features to people to enhance their knowledge and enable the people to monitor their health continuously to keep track of their physical activity by combining both externally and internally. They also keep track of the human body in physiological and in biochemical parameters during daily life. This wearable data collects the information including the vital signs such as heart rates, oxygen level, blood pressure, body temperature. They may also evolve in such a way that they tend to become skin-attachable devices. The most cutting-edge remedies for healthcare issues may be these smart wearable products. They also serve as tools for a user to manage their illness and their clients.

The study by **Crawford RJ, Filli L, Elliott JM, Nanz D, Fischer MA, Marcon M, et al.**

Published inNIH-The National center for the Biotechnology Information, has stated that the body's accumulated fat and poor muscle growth will cause numerous spinal misalignments. Functional deficiencies may be caused by lumbar muscle atrophy and fat infiltration, which are linked to spinal degenerative disorders. The biomechanical effects of spinal position on the lumbar intervertebral discs and joints are significant. When the gravity center is healthy and able to sustain both static and dynamic postures, the balanced spinal alignment optimizes muscular energy consumption and joint stress. According to the notion of spinal balance in the sagittal plane, the spine must be aligned with the pelvis and sacrum in the sagittal plane for the standing posture to be mechanically effective.

METHODOLOGY

Spinal misalignments are the most common problem peopleface in their present lifestyle. Misalignment of spine is the historical result of the degenerative discs; these degenerative discs have different reasons to get degenerated. Most of the CG lies in the human body lies in spinal cord. For women during the pregnancy time the spine undergoes heavy stresses.

Collection of data

The misalignment in spinal cord is not only one way there are so many factors affecting the misalignment of spine. Some data is being collected regarding this misalignment of spine of different body structures as they don't have a similar problem.

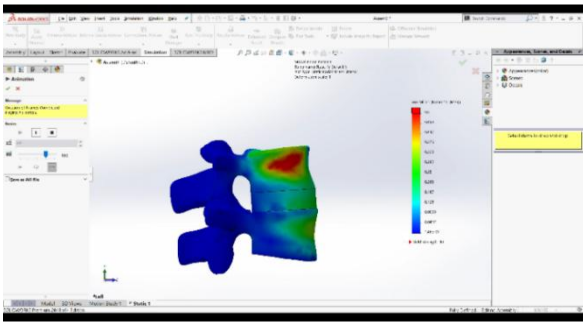

Fig. 6 FEA performed between two vertebrae of lumbar spine

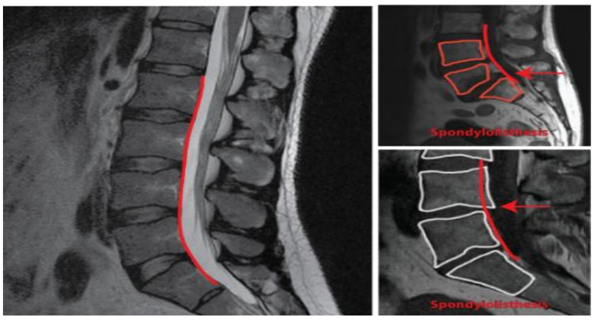

Fig.7 CT, MRI scans of misaligned Lumbar spine

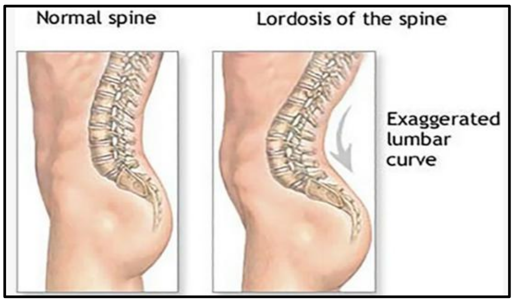

Fig. 8 Misalignment in lumbar

Ideation

The conceptual image developed illustrates the main point of this paper, which centres on the influence of health bands on individual health and wellness. The image's central element is the profile of a person who stands in for the user of a health band. The user is surrounded by a variety of health band features, such as monitoring spinal cord alignment periodically and providing essential suggestions to correct the misalignment present. The enormous quantity of data produced by these health bands is represented in the background by a variety of data representations and graphs.

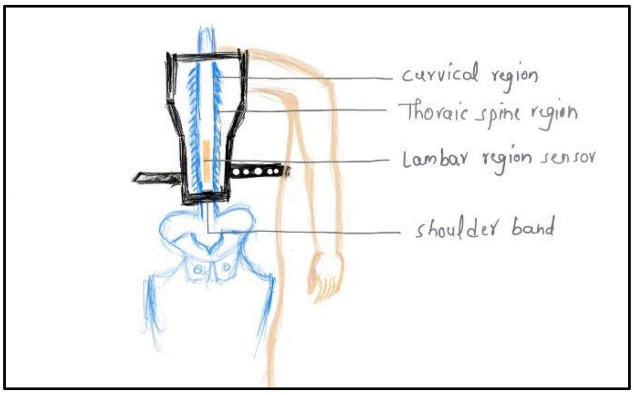

Fig.8 Conceptual drawing of the Spine wellness system

3DModel Generation

MIMICS software is an advanced tool for creating accurate and detailed 3D models from X-ray and CT images. The process of extracting 3D models using MIMICS software involves several steps. First, the images are loaded into the software and segmented to separate the area of interest from the rest of the image. The software then creates a mesh by connecting the individual pixels or voxels to create a surface that represents the object. The mesh can be refined to improve the accuracy of the model, and features such as textures and colors can be added. Finally, the 3D model can be exported in various file formats for use in other software or 3D printing.

MIMICS software is equipped with advanced features that make it an essential tool for researchers and medical professionals. For example, MIMICS allows the merging of multiple scans to create a more comprehensive 3D model. It also includes automatic landmark identification, which simplifies the process of identifying key anatomical landmarks. Additionally, MIMICS can create models based on MRI images, making it a versatile tool for a wide range of applications.

One of the significant advantages of using MIMICS software is its accuracy in creating 3D models. By utilizing segmentation and meshing algorithms, MIMICS can create models that are faithful to the original images. These models can be used for a variety of purposes, such as surgical planning, medical education, and research. For instance, researchers can use MIMICS to create detailed 3D models of specific anatomical structures for studying the effects of diseases or injuries.

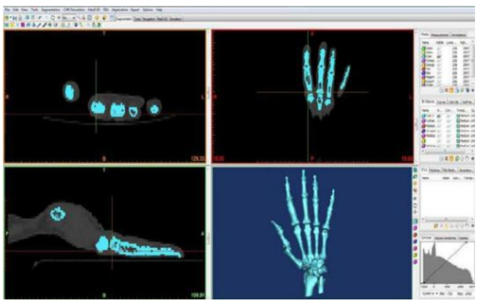

Fig.9 Extracting medical images to 3D solid models from MIMICS.

After the extraction process of the 3D model from the medical images using MIMICS software, the resulting file is converted into a solid part. This solid part file is then uploaded into Solidworks software in the SLDPRT format. The purpose of uploading the file in Solidworks is to generate G-code for the solid part. To achieve this, the SLDPRT file is converted into an STL file, which can then be used to create the 3D printing model.

Virtual Setup

In addition to an Arduino Uno, resistors, and an LED board, there is a need for a flex sensor. These are connected effectively. The Arduino Uno, which serves as the main board, is linked to all of them. All of this necessitates a resistance in accordance with the 5 volts and 3 volts of power supplied by the Arduino Uno board. All resistance values for the led board, flex sensor, and are 10K and 10K, respectively (in kilo Ohms). The connections shown in the illustration.

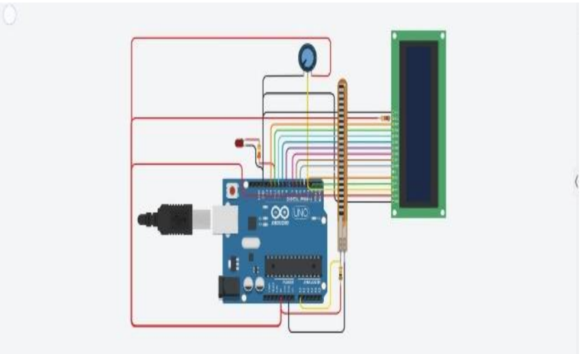

Fig.10 Virtual testing of sensor in TINKERCAD software

A flex sensor is incorporated into the lumbar region of the spine brace band, which is in the lower back area. The curvature of the lumbar region is influenced by belly fat, causing discomfort in the lower back to increase with the curvature. The sensor is calibrated using the angles observed in a healthy vertebral column, making it possible to detect spinal cord misalignments when the sensor is placed on a person with poor alignment. The process from the physical sensor to result interpretation is regulated by an Arduino Uno controller, which is situated between the sensor and the mobile result representation. Using the LED board, the Arduino Uno transmits instructions. The controller reviews and interprets the received data and provides a recommended diet and exercise plan accordingly. Based on the analyzed data, the controller provides a recommended diet and exercise schedule in response to the identified issue.

RESULT AND DISCUSSION

The sensor provides ADC values, which are used to calculate the output voltage. The output resistance is then determined based on the output voltage. The resistance values are subsequently mapped to the corresponding angles. The calibration of the resistance values for the straight and 90-degree positions varies from sensor to sensor, depending on the quality of the manufacturing process.

Output Methods

The output data obtained from the flex sensors is in the form of angular degrees. Two flex sensors are used, one of which is positioned on the lumbar region of the spine. The angles obtained from the two sensors represent the amount of deflection and displacement from the reference spine angle of the lumbar region. Thus, the resulting output is obtained by comparing and calculating the bend angles from the sensors with the reference spine posture to determine the current posture of the user's spine.

a. **Frequency Range:**

The general resistance range of the flex sensor 10000 ohms to 30000ohms

b. Sensor Testing:

Table1 flex sensor testing readings

Flex angle	Values	OHMS(x)
10	76	767-1094.4
15	102	777.9-1094
20	153	788.8-1094
30	204	799.8-1094
40	255	810.7-1094
70	408	843.6-1094
90	484	865.5-1094

Prototyping

A prototype was tested with it with different kinds of people who have a different body mass and different body geometry. People of different ages have participated in this testing right from 15years to 55years, most of the problem is seen in the elderly age group of 45-55. People of young age also got some bad results from the misaligned spine due to lack of physical maintaining of their body. 85% of people are victims of this misaligned spines in that 65% of people are elderly aged, 20% of the people are mid age group (30yrs-45yrs) and remaining 15% people are young age group (18yrs-28yrs).

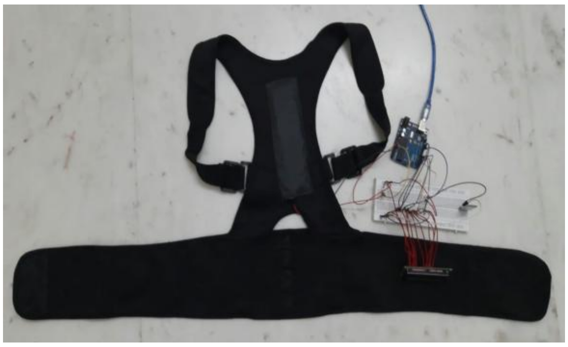

Fig. 11 Prototype of spine brace band integrated with flex sensor.

CONCLUSION

A prototype has been developed and rigorously tested on individuals spanning various age groups and body types, confirming its effectiveness and adaptability. This innovative wearable technology offers users significant advantages in terms of safety, efficiency, and comfort. It serves as a genuine augmentation of both mental and physical capabilities, enhancing overall quality of life in professional and everyday settings.

This versatile technology promises to revolutionize the user's daily life and promoting healthier living across various domains. Whether employed at work or in daily routines, this innovation has the potential to enhance the user's quality of life significantly. By integrating seamlessly into multiple facets of life, it alleviates complexities, thereby fostering a healthier and more efficient lifestyle. Its widespread application can lead to safer and more productive workplaces and promote overall well-being, ultimately contributing to an improved quality of life for individuals in all areas of use.

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