Artificial intelligence model for continuous, in-home, posture and health monitoring including user feedback and predictions of clinical assessment.

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## Introduction

According to (Gill et al., 2023) in 2020 alone, musculoskeletal disorders (MSDs) had been ranked 2nd as the leading non-fatal disability which has been affecting more than a billion people worldwide. In Finland, MSD had taken the spotlight as being the leading cause of temporal disability within the nation, through which a lot of resources allocated towards the health services (Martimo, 2010). It might be misconceived that only the elderly are the only ones that suffer from this condition. However, a report by (European Agency for Safety and Health at Work., 2021) has concluded that quite a number of individuals across different age groups are currently suffering from it. It was reported that MSDs can often originate during the childhood stage mainly due to adoption of abnormal postures and low physical activities, which subsequently lead to long-term chronic pain, discomfort, and physical limitations. Traditional examination and treatment procedures most often consist of regular clinical visits and are currently viewed as being inconvenient and costly. According to (Bevan, 2015), MSDs have said to have cost the European Union (EU) over 2% of its gross domestic product (GDP), which is estimated to be over €240bn each year. There is no doubt that this is a steadily growing concern that needs to be properly addressed.

Nowadays, most of the in-office work requires workers to be in a seated position for an extended period, which is said to have adverse effects to one’s health. According to (Arora and Khatri, 2022) and (Putsa et al., 2022), prolong sitting is one of the leading causes of MSDs among office workers. It is therefore recommended that the users should go for small walk breaks after every few hours. The integration of smart sensing chairs that would be actively monitored and provide feedback on one’s health and activity levels would be deemed quite useful.

Furthermore, with the rapid advancement in data sensor technology and Artificial Intelligence in this present age, there should be new and commercialized solutions out there in the market for continuous posture and health monitoring. There is no doubt that these types of systems have the potential of contributing towards the idea of personalized healthcare and improving the quality of life, especially for individuals that are suffering from MSDs.

With that in mind, various research studies have investigated the development of posture monitoring systems which are aimed at detecting bad sitting postures to help the end user in maintaining the right sitting posture at every given time. These types of systems are named as “smart sensing chairs” which goes all the way back to a research study done by (Tan et al., 2001), which fitted a chair with a pressure distribution sensor in order to classify a user’s sitting postures which was just first of many. Furthermore, with a lot of research papers being published in this field, this literature review aims to evaluate related studies and identify research gaps that can pave the way for further investigation into this study. By exploring existing studies, it is possible to gain a better understanding of the current state on the implementation of a smart sensing chair for posture classification and health monitoring.

## Search Strategy

This literature review paper is aimed at conducting a systematic review of similar studies done on smart sensing chair technology. Articles that were examined came from various online publication sources such as Semantic Scholar, Google Scholar, IEEE Explore to name some of them. To aid in the search for the relevant articles though different database systems, a list of important keywords was clearly defined to ensure that the most relevant papers came in the search results. Additionally, some of these keywords were combined to achieve better search results. Below are some of the search terms that was used.

1. Smart Sensing Chair
2. Sitting Posture Recognition
3. Posture Classification
4. Sitting Posture Classification using AI/Machine Learning
5. Sitting Posture Monitoring

## Sitting Posture Monitoring Systems

As previously stated, the development of a sitting posture monitoring system is not an entirely new concept, rather it is an area that has been explored by multiple researchers in the past until this present day. This section would be going over different research projects that developed their variation of smart sensing chairs. To efficiently conduct this literature review, at least 30+ relevant research literatures were carefully selected and examined as seen in Table 1. have been published focusing on the of the use of unobtrusive means for the classification of different sitting positions. Systematically examining these papers would surely some shed light on the most common machine learning algorithms and sensors being used to be able to classify various sitting postures.

### History of Smart Sensing chairs

As previously stated, (Tan et al., 2001) was the first research seen to pioneer the idea of a smart sensing chair that is capable of detecting one’s posture by using pressure distribution sensors integrated into the chair. Over the past few years, various research studies have implemented different variations of these smart sensing chair concepts ranging from different sensors to various classification methods to posture detection as shown in Figure 1. Furthermore, a literature connection map (on similar studies) done on smart sensing chairs was constructed as shown in Figure 2 below. This figure gives a rough visualization of the amount of research being done in landscape of smart sensing chair technology.



Figure – Timeline Map of Similar Literatures

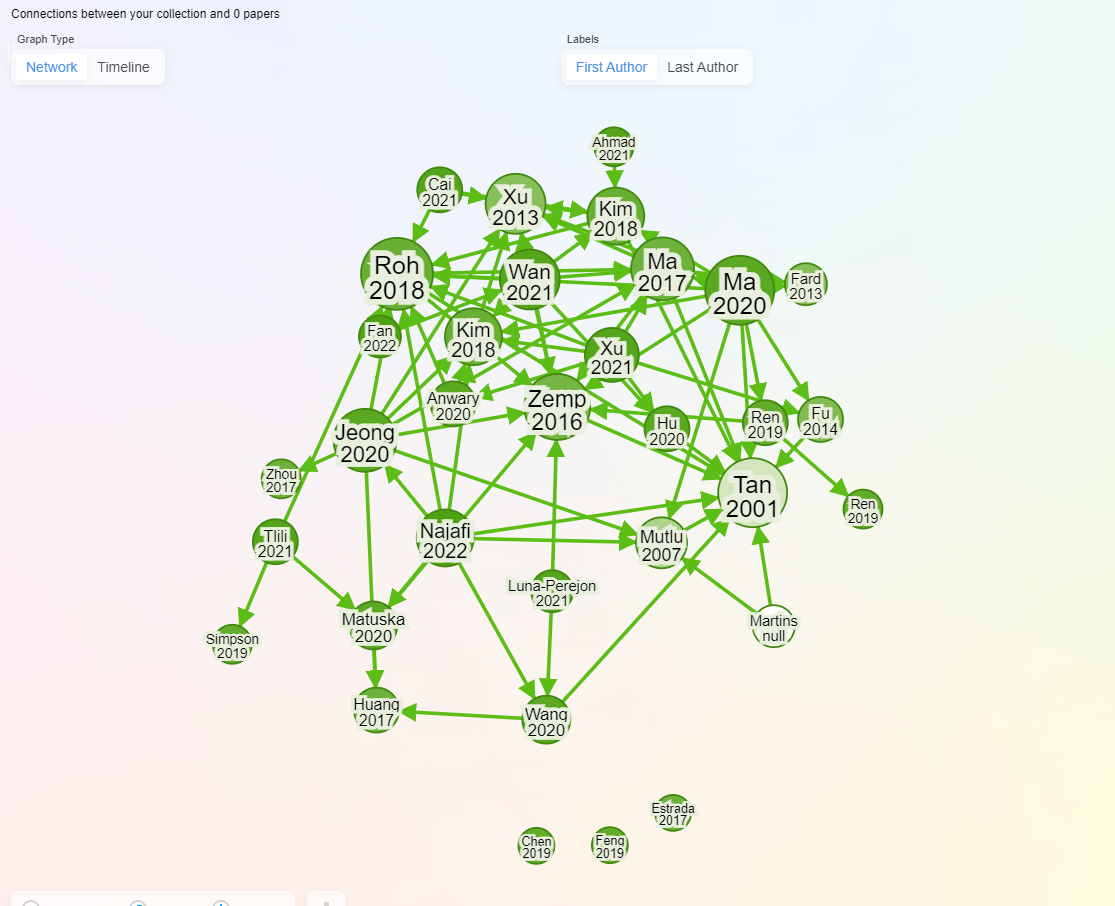


Figure - A Map of Similar Studies on Smart Sensing Chairs

## Sensor systems

As anticipated, various scholarly papers use different types of sensor devices to detect different sitting postures. Overall, they can be divided into 3 overarching categories:

* Smart Sensing Chairs using Pressure Sensors
* Smart Sensing Chairs using Flex Sensors
* Smart Sensing Chairs using Computer Vision Systems
* Smart Sensor Chairs using Mixed Sensor Systems

### Sensing Chair using Pressure Sensors

##### Force Sensing/Sensitive Sensor (FSR)

Force Sensing Resistors are also known as force sensors which are commonly used to measure the forces applied to its surface area. These sensors work by varying their output resistance based on the pressure being applied to it. Typically, the overall resistance decreases as more pressure is applied (Sadun et al., 2016). To be able to get the reading from this sensor, it normally connected directly to a microcontroller such as an Arduino or like get its reading. Figure 1 shows an example of how a FSR sensor commonly looks like.



Figure 3- A Force Sensing Resistor

Focusing on studies that integrated FSRs in to their studies, (Mutlu et al., 2007) integrated 19 different FSRs into the seating cushion and used the SimpleLogistic ML algorithm to achieve 78% accuracy in classifying 10 different postures. (Tsai et al., 2023) used 13 pressure sensors classify 10 sitting postures and was able to achieve an accuracy of 99.10% using the SVM ML algorithm. (Aminosharieh Najafi et al., 2022) applied 8 sensors (4 on the seating cushion and 4 on the back rest) and used EMN algorithm to classify 8 sitting posture and achieved an accuracy of 91.68%. In addition to this, there was a Desktop Graphical User Interface (GUI) application which displayed the senor reading in real-time. (Luna-Perejón et al., 2021) add 6 sensors placed on the seating cushion and resulted 81.5% classification accuracy using SOM (ISOM-SPR) ML algorithm.

##### Load Cells

Load cells are another variation of force sensor which is commonly used to measure monitor sitting postures. Under the hood, it works by converting the mechanical force being applied to it into digital signals which can be read by microcontrollers. (Roh et al., 2018) developed a smart chair by integrating 4 load cell sensors within the chair sitting cushion to classify 6 sitting postures. An accuracy of 97.94% was achieved using a SVM (RBF kernel) ML model. Similarly, (Pereira and Plácido Da Silva, 2023) follows similarly and placed 3 load cells to classify 8 sitting postures and was able to a classification accuracy of 98.50%.

##### Textile Pressure Sensor

### Sensing Chair using Flex Sensors

### Sensing Chair using Mixed Sensors

These are smart sensing chairs that utilize at least 2 different types of sensor devices which work hand in hand to classify different sitting postures. (Ma et al., 2020) developed a smart seating cushion which employed the use 6 FSR sensors for detecting different sitting postures and an Inertial measurement unit (IMU) sensor to monitor user activity.

### Sitting Posture Classification

### (Internet of Things) IoT Integration and Connectivity

(Ma et al., 2020) emphasized on the use of IoT-Based technology in it being capable of seamless monitoring seating activities.

### Health and Wellbeing Monitoring

### Ethical Considerations

### Challenges and Limitations

### Comparative Analysis of systems

### Sensor Technology

Upon in-depth evaluation of the research papers, it was seen that there are different variations of sensor technology being used in the classification of different sitting postures. Overall, it was concluded that **Force Sensitive Resistors** (FSRs) and **Load Cells** were 2 of the most widely used sensors of choice in the classification of different sitting postures.

Mixed Sensor System

#### Other types of sensors

* Web cameras
* RFID
* Multi-Sensor Combinations

### Different Sitting postures

### Smart Wheelchair Systems

### User Feedback System

### Machine Learning Algorithms

CNN

ANN

### Quality of Testing Data

### Research Gaps

* Most research stops at the posture classification phase.
* Not much effort is focused on the user feedback aspects.

### Future Directives and Trends

### The use and impact of Mobile apps in the healthcare sector

The use of mobile phones in the healthcare sector has rapidly been gaining in popularity in recent times. Mobile Health (MHealth) apps are mobile applications that are mostly tailored towards assisting both medical professionals and patients in the aspects of health management. According to (Lohnar, 2016), the number of mHealth apps are expected to be on an upward trend.

According to various studies, there are a series of hurdles and issues that must be put into consideration during the implementation of mHealth app.

### Commercialization

## Conclusions

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## Appendixes

Tables 1 – Sitting Posture Monitoring Research Papers

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Reference** | **Sensors** | **Number of Postures** | **Classification Method** | **Classification Accuracy** | **Test Subjects** | **Limitations** | **User Feedback System** | **Is Realtime** |
| (Pereira and Plácido Da Silva, 2023) | Load Cell - Posture Conductive Nappa - ECG | 5 | K-NN | 98.50% | 10 | Not used in a real-life setting | |  |
| (Ahmad et al., 2021) | Screen Printed Pressure units (16 Array) | 4 | LightGBM | 99.03% | 32 | Not used in a real life setting | |  |
| (Huang et al., 2017) | 52 by 44 Piezo-Resistive Sensor Array | 8 | ANN | 92.20% |  | No accuracy |  |  |
| (Martínez-Estrada et al., 2023) | 10 Presence textile capacitive sensor (embroidered) | 8 |  |  | 5 |  |  |  |
| (Matuska et al., 2020) | 6 Flexible Force Sensors | 9 | Average Standard deviation with 3 Threshold values to determine good/bad postures (Non AI) |  | 12 |  |  |  |
| (Aminosharieh Najafi et al., 2022) | 8 Force Sensing Resistors | 8 | EMNM | 92.68% | 40 |  |  |  |
| (Kundaliya et al., 2022) | A502 Force Sensor & Flex Sensor | 5 |  |  |  | No accuracy |  |  |
| (Ran et al., 2021) | Pressure Array (IMMM00014, I-MOTION | 7 | 5 Layer Artificial Intelligence | 97.07% | 100 |  |  |  |
| (Roh et al., 2018) | 4 Load Cells | 6 | SVM using RBF kernel | 97.94% | 24 | No accuracy |  |  |
| (Kim et al., 2018) | Textile Pressure Sensors (Conductive Ni-Ti alloy fiber) | 7 |  |  |  | No accuracy |  |  |
| (Feng et al., 2019) | RFID tags | 3 | RF | 99.27% | 14 | Small number of postures | |  |
| (Hu et al., 2020) | 6 Flexible Force Sensors | 7 | 2 Layer ANN | 97.43% | 11 |  |  |  |
| (Jeong and Park, 2021) | 6 Pressure Sensors & 6 Infrared Reflective Distance Sensors | 11 | K-NN | 92% | 36 |  |  |  |
| Martins et al. 2013 | 8 | ANN | 93.40% | 30 |  |  |  | |
| (Mutlu et al., 2007) | 10 | SimpleLogistic | 87% | 46 |  |  |  | |
| (Ma et al., 2017) | 5 | Decision Tree (J48) | 99.47% | 12 |  |  |  | |
| (Zemp et al., 2016) | 16 Force Sensor | 7 | Random Forest | 81% - 98% | 41 |  |  |  |
| (Tsai et al., 2023) | 13 pressure sensors (FSR-406) | 10 | SVM (Linear) | 99.10% | 20 |  |  |  |
| (Kim et al., 2018) | 8x8 Pressure Sensor | 5 | CNN | 95.30% | 10 |  |  |  |
| (Luna-Perejón et al., 2021) | 6 Force Sensitive Resistors (FSR) | 7 | ANN | 81.00% | 12 | Low accuracy |  |  |
| (Cai et al., 2021) | 3x3 Flexible Array Pressure Sensor | 6 | SOM (ISOM-SPR) | 95.67% | 40 | Few Test Samples | Mobile App |  |
| (Fan et al., 2022) | 44 × 52 Pressure Sensor Array | 5 | CNN | 99.82% | 8 | \_ Few Test Samples \_ Lack of detection of spine curvatures | N/A | YES |
| (Chen, 2019) | Astra3D Sensor |  | CNN | 90% |  | Privacy issue with Camera Can't work in bad lighting Lack of proper user feedback system for posture correction | PC Screen (Correct/Wrong) | YES |
| (Ma et al., 2020) | Pressure array | 5 | Decision Tree | 89% |  |  |  |  |
| (Fard et al., 2013) | 64 Pressure Sensors Array (40x50) cm2 | 4 |  |  | 5 | Limited number of subjects | N/A | NO |
| (Ren et al., 2019) | 6 Square-Type force Sensing Resistors |  | ANN |  |  |  | RGB LED | YES |
| (Wang et al., 2021) | 2 Pressure Sensors Array (FSR) | 15 | SNN (LSM) | 88.52% | 19 | Lack of focus on the User feedback aspects Not used in real-life setting to prove it's usefulness | Desktop App | YES |
| (Xu et al., 2013) | Electrical Textile | 7 | Naive Bayes Network | 85.90% | 14 | The mobile just visualizes the sitting pressure distribution, however the value of this is not really seen to the end user's persepective. No sort of recommendation system. | Mobile App | Yes |
| (R et al., 2023) | Web Camera | 6 | RCNN & CNN | 92.50% |  | No good user feedback/recommendation system | N/A | YES |
| (Fu and Macleod, 2014) | 8 Force Sensing Resistors (FSR) FSR 406 |  | HMM Decision Tree |  |  | Lacks Proper testing  There's a need to implement a feedback system | N/A | YES |