Article

A Smart System for Continuous Sitting Posture Monitoring and Assessment

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**Abstract: <<**TO BE FILLED>>.

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1. Introduction

1.1 Background and Motivation

In this present day and age, sedentary behaviors such as sitting has become a fundamental part of one’s lifestyles, especially among office workers. These individuals often find themselves confined to a desk, in front of a computer screen for an extended period; a pattern that has proven to be detrimental to one’s health [1,2]. According to the World Health Organization (WHO), the economic burdens attributed to sedentary behaviors is costing around US$ 27 billion annually and is expected to reach US $300 billion by the year 2030 [3].

The adoption of an improper sitting postures such as slouching and asymmetric sitting is a contributing factor that further increases the risk of several health issues, ultimately negatively affecting the quality of life. This bad habit is not just prevalent among the elderly population, but also across individuals within different age groups [4]. Over a long-term period, this could thereby lead to the development of chronic health issues such as lower back pains [5] and other musculoskeletal conditions [6]. Hence, it is naturally advised by doctors and healthcare professionals to consistently maintain an upright sitting posture by having your back in a straight position or perpendicular to the seat’s backrest. Furthermore, in addition to maintaining an upright sitting posture, it is also recommended to avoid sitting for a long period of time or maintaining a singular posture for a long duration [7,8]. Additionally, it is advised to take squeeze in a few walking breaks after a given period.

Furthermore, to help combat this issue, various researchers have explored the use of smart sensing chair systems which are capable of can detect various sitting postures, thereby guiding the end user to enforce proper sitting habits. So far, various methods have been employed in the development of such systems ranging from different classification methods, sensor placement configuration, and sensor types. A recent study by [9] highlighted a gap in the current research landscape which found that the vast majority of the similar studies primarily focus just on the detection of different sitting postures and achieving high classification accuracy. There is no doubt that there are integral in the development of such system, however there is more that can be done in improving the feedback mechanism that is bring provided back to the end user, subsequently encouraging and motivating them to adopt proper sitting postures.

1.2 Objective of the Study

The aim of this study is to develop a robust machine-leaning model capable of detecting different sitting postures as well as creating a comprehensive posture monitoring system that not only classifies different sitting postures, but also intelligently scores them. Additionally, this study also looks provide real-time feedback system which would display relevant statistical insights based on the posture dataset back to the end-user.

2. Related Works

Over the recent years, there has been a rise in the number of research studies conducted on smart seating systems, capable of intelligently classifying various sitting postures. Across some the research studies found, it was apparent that there are various methods being employed ranging from the classification algorithms to the sensor types. Furthermore, one of the first research paper published that pioneered the idea of a smart sensing chair system was by Tan el. [10] back in 2001. They were able to classify 14 different siting postures using a (Principal Component Analysis)-based algorithm which interfaced with pressure sensor array module placed the both the back rest and the sitting area of the chair; achieving an overall accuracy ranging between 79% to 96%. Subsequently, a lot of research studies has been published primarily following a very similar approach.

2.1 Sensor Technology

The sensor being integrated is one of the key components in the development of smart sensing systems, as it plays a key role in capturing one’s sitting pattern which would subsequently be classified by a detection algorithm. Furthermore, across the research studies found, there are 2 categories of sensors in which sitting postures can be detected which are wearable and non-wearable. Those under the wearable category involved the use of sensors such as accelerometers, gyroscopes, and inertial measurement units. On the other hand, there are the non-wearable systems which do not require the individual to directly put on or wear the sensor, promoting its non-invasive nature. These types of sensors mostly used which are pressure sensors, load cells, cameras, flex sensors and distance sensors. According to a study by Odesola et al. in 2024 [9], the pressure sensor was seen as the most popular option among related studies.

Wang et al. [11] developed a smart chair system equipped with 2 (9x9) & (10x9) FSR pressure matrix which were used to classify up to 15 different sitting postures using the SNN (Spike Neural Networks). Tsai et al. adopted a similar approach by using a textile-based pressure sensor array in order to classify 7 sitting postures while achieving an overall classification accuracy of 85.9%.

2.2 Machine Learning Techniques

The ability for a smart sensing chair in the detection multiple sitting postures significantly lies in the posture detection algorithm being employed. Hence, various types of machine learning tool and statistical models are being used to identify a wide range of sitting postures with high classification accuracy.

2.3 Feedback Mechanism

There is no doubt that achieving high posture classification accuracy is crucial among smart sensing chair systems. However, this alone doesn’t bring any value back to the end user. What is also needed is a feedback mechanism that would both inform and encourage the end user to adopt “proper” sitting postures while also providing valuable insights that would improve their overall sitting pattern. Whenever a bad sitting posture is detected for a long duration of time, the user should be alert in one way or another to correct it. Within the current research landscape, there are multiple ways that a user could be alerted. Mobile phones have been emerging as a popular medium for collecting and displaying useful feedback back to the end user. Cai et al. [12] developed a smart sensing chair system which relayed the detected posture via a mobile app. Additionally, Cho et al [13] also developed a similar mobile app which provided statistical insights along with recommended YouTube videos largely based on the sitting postures being adopted.

There are also other ways that the end user could be notified or alerted whenever an incorrect sitting posture is being adopted. Ran et al. [14] and Ishac et al. [15] integrated haptic motors into the seating cushion which vibrated whenever an improper sitting posture is being detected which continues until an upright posture has been achieved by the individual. On the other hand, Ren et al. [16] incorporated the use of a RGB led light strip which changed in color whenever the individual needed to change their sitting posture and taking microbreaks.

Overall, it was seen that the feedback mechanism implemented among existing studies were severely lacking mainly in its informative elements and valuable insights which ideally should encourage the adoption of proper sitting postures among individuals. Most systems simply just focused on displaying the current posture being adopted without any form of valuable feedback mechanism. While most smart-sensing systems can detect and identify various sitting postures, there are some feature sets that are absent such as real-time feedback and posture scoring mechanism which would rate and provide a score on the current posture being adopted. From the end user’s perspective, is there any certainty that the implemented feedback system has achieved its goal of inciting adopting of proper sitting postures? Furthermore, with the lack of comprehensive feedback of such systems, a lot of questions can be raised regarding both its usability and effectiveness in a real-life setting. Hence, there is a need for a comprehensive system in place to access whether the implemented feedback mechanism as achieved its desired expectations.

3. Methodology

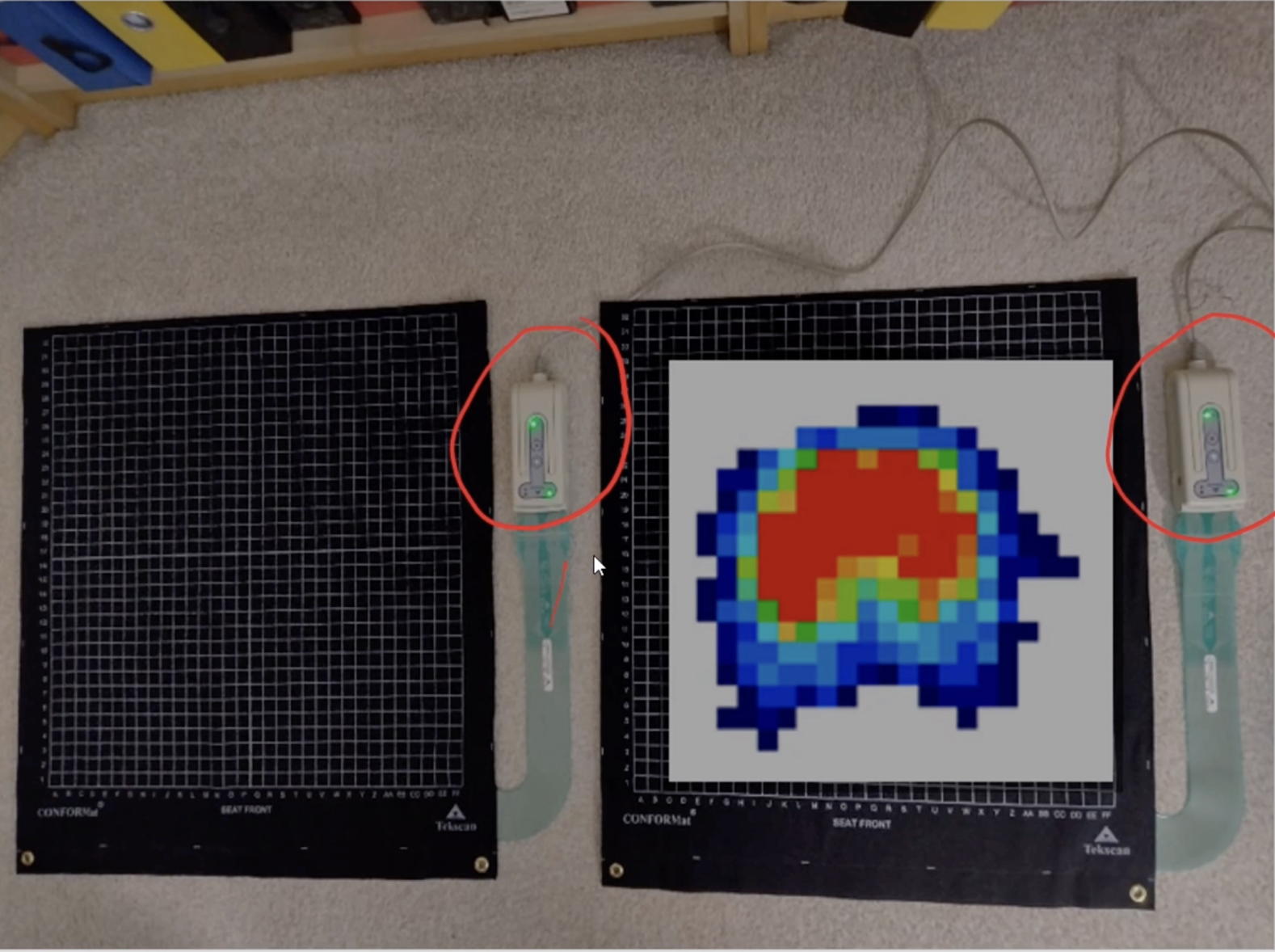
In this paper, a smart sensing chair system is developed classify different sitting postures using a FSR pressure sensor array. This study will be focusing on 5 sitting postures with are upright, slouching, leaning right, leaning left, leaning back as shown in Figure 1. Additionally, a novel feedback software application will be developed to provide valuable health insights which aims to encourage the end user to adopt proper sitting postures.

In order to capture the entire sitting posture of an individual, 2 (32x32) CONFORMat pressure sensor arrays which will be placed on the backrest and the seating cushion of the chair. The pressure sensor mat was developed by a company called Tekscan who specializes in the manufacturing of pressure measure sensor units [17].

A diagram of a person sitting in a chair

Description automatically generated

**Figure 1**. 5 different sitting postures. (SP1) Upright, (SP2) Slouching, (SP3) Leaning Left, (SP4) Leaning Right, (SP5) Leaning Back.



**Figure 1**. Tekscan Sensor mat

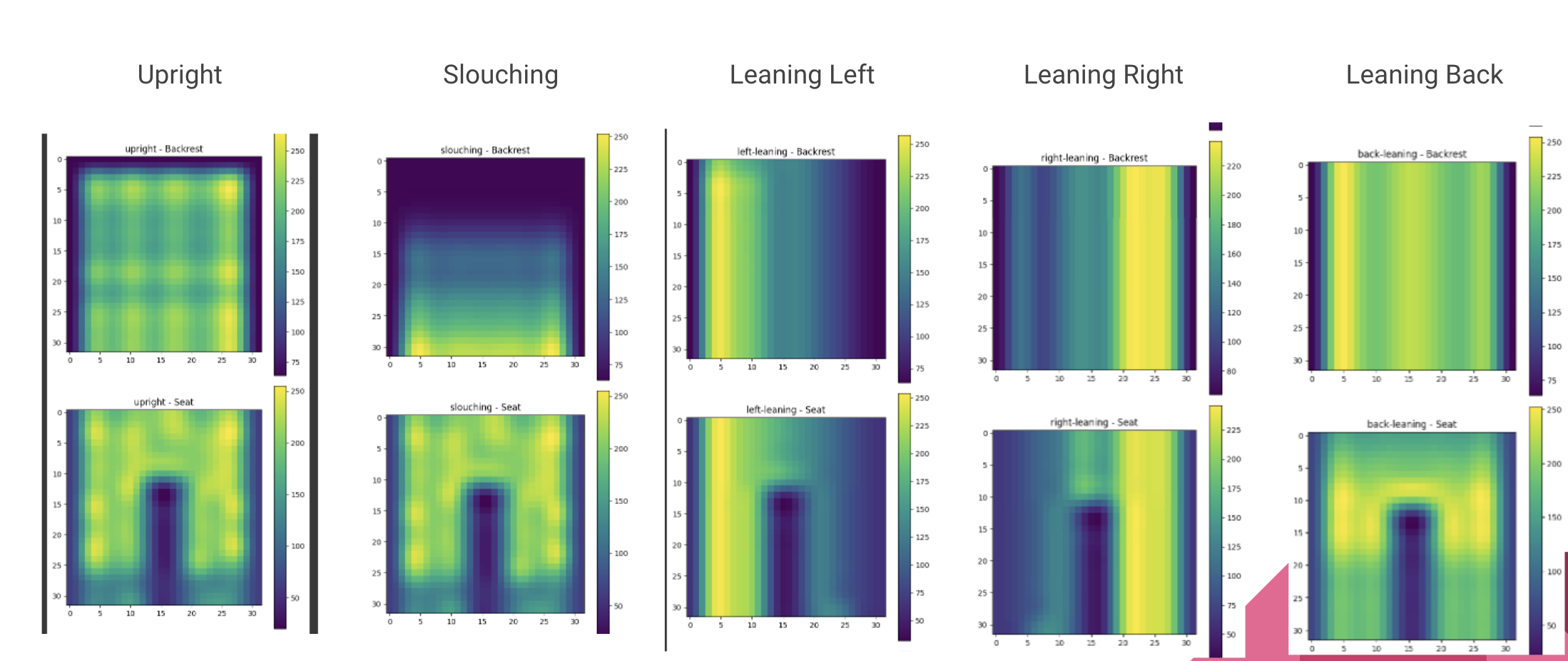
3.1 Data Collection

3.1.1 Participants

3.1.2 Experimental Setup

Java 2 
GORITHMS 

3.2 Machine Learning Algorithm



3.3 Posture Monitoring and Scoring System

4. Results and Discussion

4.1 Performance of the Machine Learning Algorithm

A graph of different models

Description automatically generated

4.2 Effectiveness of the Posture Monitoring System

4.3 Statistical Analysis of Sitting Patterns

4.4 Interpretation of Results

4.5 Limitations of the Study

4. Discussion

5. Conclusions

This is the conclusion section

**Supplementary Materials:** The following supporting information can be downloaded at: www.mdpi.com/xxx/s1, Figure S1: title; Table S1: title; Video S1: title.

**Author Contributions:** <Author’s contributions>

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**Data Availability Statement:** We encourage all authors of articles published in MDPI journals to share their research data. In this section, please provide details regarding where data supporting reported results can be found, including links to publicly archived datasets analyzed or generated during the study. Where no new data were created, or where data is unavailable due to privacy or ethical restrictions, a statement is still required. Suggested Data Availability Statements are available in section “MDPI Research Data Policies” at https://www.mdpi.com/ethics.

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**Conflicts of Interest:** The authors declare no conflicts of interest.

**Appendix A**

Appendix content

**Appendix B**

Appendix content

References

1. Daneshmandi, H.; Choobineh, A.; Ghaem, H.; Karimi, M. Adverse Effects of Prolonged Sitting Behavior on the General Health of Office Workers. *J Lifestyle Med* **2017**, *7*, 69–75, doi:10.15280/jlm.2017.7.2.69.

2. Keskin, Y. Correlation between Sitting Duration and Position and Lumbar Pain among Office Workers. *Haydarpasa Numune Med J* **2019**, doi:10.14744/hnhj.2019.04909.

3. *Global Status Report on Physical Activity 2022*; World Health Organization: Geneva, 2022; ISBN 978-92-4-005915-3.

4. Yang, L.; Lu, X.; Yan, B.; Huang, Y. Prevalence of Incorrect Posture among Children and Adolescents: Finding from a Large Population-Based Study in China. *iScience* **2020**, *23*, 101043, doi:10.1016/j.isci.2020.101043.

5. Kett, A.R.; Sichting, F.; Milani, T.L. The Effect of Sitting Posture and Postural Activity on Low Back Muscle Stiffness. *Biomechanics* **2021**, *1*, 214–224, doi:10.3390/biomechanics1020018.

6. Susilowati, I.H.; Kurniawidjaja, L.M.; Nugraha, S.; Nasri, S.M.; Pujiriani, I.; Hasiholan, B.P. The Prevalence of Bad Posture and Musculoskeletal Symptoms Originating from the Use of Gadgets as an Impact of the Work from Home Program of the University Community. *Heliyon* **2022**, *8*, e11059, doi:10.1016/j.heliyon.2022.e11059.

7. Stephens, M.; Bartley, C.A. Understanding the Association between Pressure Ulcers and Sitting in Adults What Does It Mean for Me and My Carers? Seating Guidelines for People, Carers and Health & Social Care Professionals. *Journal of Tissue Viability* **2018**, *27*, 59–73, doi:10.1016/j.jtv.2017.09.004.

8. Benatti, F.B.; Ried-Larsen, M. The Effects of Breaking up Prolonged Sitting Time: A Review of Experimental Studies. *Medicine & Science in Sports & Exercise* **2015**, *47*, 2053–2061, doi:10.1249/MSS.0000000000000654.

9. Odesola, D.F.; Kulon, J.; Verghese, S.; Partlow, A.; Gibson, C. Smart Sensing Chairs for Sitting Posture Detection, Classification, and Monitoring: A Comprehensive Review. *Sensors* **2024**, *24*, 2940, doi:10.3390/s24092940.

10. Tan, H.Z.; Slivovsky, L.A.; Pentland, A. A Sensing Chair Using Pressure Distribution Sensors. *IEEE/ASME Trans. Mechatron.* **2001**, *6*, 261–268, doi:10.1109/3516.951364.

11. Wang, J.; Hafidh, B.; Dong, H.; El Saddik, A. Sitting Posture Recognition Using a Spiking Neural Network. *IEEE Sensors J.* **2021**, *21*, 1779–1786, doi:10.1109/JSEN.2020.3016611.

12. Cai, W.; Zhao, D.; Zhang, M.; Xu, Y.; Li, Z. Improved Self-Organizing Map-Based Unsupervised Learning Algorithm for Sitting Posture Recognition System. *Sensors* **2021**, *21*, 6246, doi:10.3390/s21186246.

13. Cho, H.; Choi, H.-J.; Lee, C.-E.; Sir, C.-W. Sitting Posture Prediction and Correction System Using Arduino-Based Chair and Deep Learning Model. In Proceedings of the 2019 IEEE 12th Conference on Service-Oriented Computing and Applications (SOCA); IEEE: Kaohsiung, Taiwan, November 2019; pp. 98–102.

14. Ran, X.; Wang, C.; Xiao, Y.; Gao, X.; Zhu, Z.; Chen, B. A Portable Sitting Posture Monitoring System Based on a Pressure Sensor Array and Machine Learning. *Sensors and Actuators A: Physical* **2021**, *331*, 112900, doi:10.1016/j.sna.2021.112900.

15. Ishac, K.; Suzuki, K. LifeChair: A Conductive Fabric Sensor-Based Smart Cushion for Actively Shaping Sitting Posture. *Sensors* **2018**, *18*, 2261, doi:10.3390/s18072261.

16. Ren, X.; Yu, B.; Lu, Y.; Chen, Y.; Pu, P. HealthSit: Designing Posture-Based Interaction to Promote Exercise during Fitness Breaks. *International Journal of Human–Computer Interaction* **2019**, *35*, 870–885, doi:10.1080/10447318.2018.1506641.

17. Tekscan Tekscan Available online: https://www.tekscan.com (accessed on 8 October 2024).

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