AN INTELLIGENT MOBILE DEVICE TO ASSIST IN PRESSURE REGULATION AND MEASUREMENT IN THE SOLE AREA OF THE HUMAN FOOT WHEN PLAYING GOLF USING THERMAL MEASURE AND MOTION DETECTION

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ABSTRACT

Flat feet and inconsistent power transfer in sports like golf can lead to discomfort, reduced performance, and long-term injury risks. To address these issues, I propose a wearable pressure device that helps golfers regulate power transfer while also reducing pain for individuals with flat feet [1]. The device uses a Velostat pressure sensor and a Boron microcontroller to monitor pressure distribution and motion in real time, providing feedback to optimize stance and balance. Key challenges included ensuring accurate sensor calibration and integrating reliable wireless data transmission, which were addressed through iterative testing and software adjustments. The device was tested in scenarios involving walking, standing, and golf swings to assess pressure patterns and user comfort. Results showed improved balance awareness and reduced foot strain over repeated use [2]. This solution offers a versatile, accessible tool that improves athletic performance and daily comfort, making it a valuable advancement in wearable sports and health technology.

KEYWORDS

Golf, Thermal, Motion Detection/Pressure, Sole

1. INTRODUCTION

The main problem I am trying to solve is the feeling of pressure underneath the feet when golfers are attempting to make a golf swing. As a golfer myself, I have experienced many difficulties regulating my pressure to hit the perfect golf shot, and I have seen many of my golfing peers experience the same problem [3]. Pressure regulation is especially important in the golf swing because it is the fundamentals of how a golfer generates speed and power during their swing. If this problem goes on for too long, a player may experience problems with power transition, and not be able to strike the ball as far as they wanted. More, importantly, this problem could even affect their swing consistency and make direction control and contact with the ball really difficult to maintain. For example, Bryson Dechambeu, a well-known professional golfer, had problems with swifting pressure in his swing. This is due to his unique swing mechanic where he generates a lot of power with a very large swift in weight, and he encounters problems when it is not executed correctly.

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Pressure Sensing:

Pressure sensing aims to give real-time feedback on force distribution during movement. However, da Silva (2024) notes it suffers from calibration drift and reduced sensitivity over time. My project improves this by combining pressure data with motion detection, providing more accurate, personalized feedback rather than relying solely on pressure readings.

Motion Detection with Boron Microcontroller:

Motion detection tracks body movement, but many systems fail to integrate it with pressure data, risking misinterpreted results (da Silva, 2024). My device improves on this by using the Boron Microcontroller to process both motion and pressure simultaneously, creating a synchronized system that enhances accuracy and provides clearer feedback on inefficient movements.

Comfort and Wearability:

Wearability focuses on ensuring devices are comfortable for long-term use, yet many wearables prioritize data collection over comfort, limiting user adoption (da Silva, 2024). My device addresses this by using thin Velostat sheets and lightweight materials, creating a flexible, unobtrusive design that encourages extended wear without sacrificing data quality.

I believe our device is the best solution to fixing the problem of golfers' difficulty when regulating pressure swifts. This is because compared to the other devices, such as golf rubber pressure pedals, those pedals can help you physically feel your weight shift, however, it makes it difficult during a real golf swing. From my own experience, the pedals can get in my way when I am practicing swings, and even throw me a bit too much off balance. When you look at our product, it is a device that can be worn directly under a player's feet and connected to a mobile device to give the player direct statistical feedback. Additionally, the player will feel less discomfort when swinging compared to other physical equipment and can swing more naturally and also more accurate results.

This project included two key experiments to evaluate the functionality of the wearable pressure and motion detection system. The first experiment tested the device's ability to distinguish between golf swings and walking steps. Participants performed both actions while wearing the device, and manual labels were used as ground-truth data. The system demonstrated high accuracy, correctly identifying most actions with an average detection rate of 90% for swings and 97% for steps. Slight inconsistencies occurred when swing motions were slower or less defined, indicating a need for improved motion classification. The second experiment measured the system's pressure response time [4]. Users applied force in various ways—quick taps, gradual presses—and the time delay between pressure application and device response was recorded. The average response time was 313.5 milliseconds, indicating that the system reacts promptly to user input. These experiments confirmed that the device performs reliably, but also highlighted areas for future refinement in motion sensitivity and latency.

2. CHALLENGES

In order to build the project, a few challenges have been identified as follows.

2.1. Velostat Pressure Sensor

One major component of my device is the integration of the Velostat pressure sensor with the Boron Microcontroller to detect and interpret foot pressure and motion data. Several potential problems could arise with this component. First, inconsistent sensor readings could occur due to variability in foot pressure or sensor placement. To address this, I could use signal smoothing techniques or calibrate the sensor input using baseline pressure values unique to each user.

2.2. Data Transmission

Second, data transmission issues might affect real-time feedback, especially if the device is intended to connect to an external display or app. I could use optimized, low-latency communication protocols like BLE (Bluetooth Low Energy) to maintain a reliable connection while conserving power.

2.3. Power Management

Lastly, power management is a crucial concern for wearable technology. To prevent frequent charging or battery drain, I could incorporate a power-efficient sleep mode on the Boron Microcontroller and limit data transmission to key activity moments rather than continuous streaming.

3. Solution

The main structure of my program is built around three major components: the Velostat pressure sensor, the Boron Microcontroller, and the data output system (which could include a mobile interface or LED indicators).These components work together in a logical flow to monitor and respond to the user's foot pressure and motion in real time.

Input Stage (Velostat Sensor): The program begins by continuously gathering data from the Velostat pressure sensor, which detects changes in force and pressure under the user's foot. This data reflects how pressure is distributed during walking or while swinging a golf club.

Processing Stage (Boron Microcontroller): The raw sensor data is sent to the Boron Microcontroller, which processes the information using a programmed set of thresholds and conditions. This stage includes interpreting pressure patterns, detecting shifts in weight, and identifying improper force transfer or flat-footed movement [5].

Output Stage (Feedback Mechanism): Based on the processed data, the microcontroller sends signals to a feedback system, either a mobile app, vibration motor, or LED indicator to notify the user of necessary adjustments or pressure imbalances [6].

The flow of the program moves from sensor input → data processing → user feedback. This cycle runs continuously, allowing for real-time monitoring and response.

I used Particle Boron (a microcontroller with cellular capabilities), Velostat sensors for pressure sensitivity, and Arduino-based coding to create the logic and response system for the device.

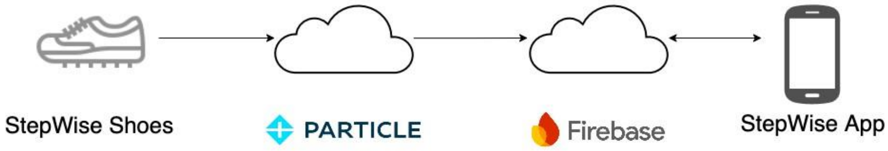

Figure 1. Overview of the solution

The Boron Microcontroller serves as the processing unit of the device. Its primary purpose is to collect and interpret pressure data from the Velostat sensor and then determine the appropriate feedback to give the user based on that data. To implement this system, I could use Particle's Device OS and cloud platform for programming, communication, and remote firmware updates [7]. This component relies on the concept of real-time data processing and threshold-based logic. In broad terms, it takes analog input from the pressure sensor, converts it to a digital signal, and compares the values against preset pressure thresholds. If a certain pressure pattern or imbalance is detected, such as excessive heel pressure in flat-footed walking or uneven foot loading during a golf swing, it triggers a response mechanism (like a vibration or visual alert).

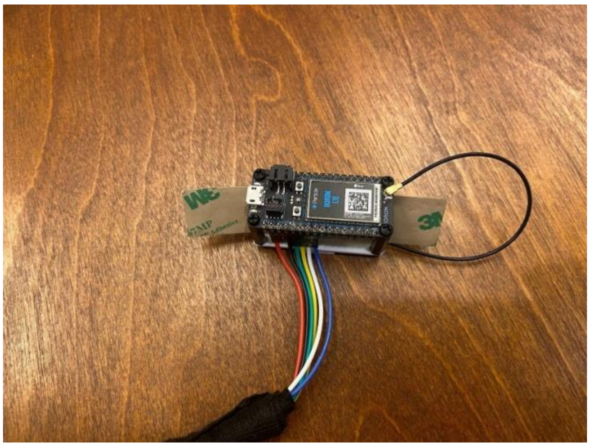

Figure 2. Picture of the component

```
int l_forefoot = analogRead(A0);
int l_heel = analogRead(A1);
int r_forefoot = analogRead(A2);
int r_heel = analogRead(A3);


sprintf(upload_data,
      "{\"l_forefoot\": \"%u\", \"l_heel\": \"%u\", \"r_forefoot\": \"%u\",\"r_heel\": \"%u\", \"start\": \"%u\"}",
      l_forefoot,
      l_heel,
      r_forefoot,
      r_heel,
      start_time
  );
Particle.publish("Hello_Samuel", upload_data, PRIVATE);
```

Figure 3. Screenshot of code 1

This code is part of a system designed to monitor foot pressure using Velostat sensors. It reads analog input values from four sensors placed on the forefoot and heel of each foot using analogRead() on pins A0 through A3 [8]. These values represent how much pressure is being applied at each location. The data is then formatted into a JSON string using sprintf(), which includes the sensor readings and a start_time variable, likely indicating when the measurement was taken. This JSON string is stored in the upload_data buffer. Finally, the code uses Particle.publish() to send the data wirelessly to the Particle Cloud under the event name

"Hello_Samuel". The PRIVATE parameter ensures the data is only visible to the authenticated user. This setup enables real-time remote monitoring of pressure distribution, which is useful for applications such as gait analysis, injury prevention, and performance improvement in activities like walking or golf.

The Velostat sensor acts as the primary input for pressure data. It constantly feeds live values to the Boron Microcontroller, which processes this information to determine whether the user is applying pressure in a balanced, healthy way (for flat-foot users) or executing proper weight transfer (for golfers). It's the starting point for all real-time decision-making in the device [9].

This component uses the concept of variable resistance under pressure, a simple principle in electronics that allows analog pressure sensing. As pressure increases, resistance decreases—this change can be measured and used to track pressure points.

Figure 4. Paper

The motion detection provides context to pressure data [10]. For instance, during a golf swing, the device can detect if weight transfer was delayed or uneven. For walking, it can recognize if a user is favoring one side, which could indicate pain or improper foot placement. It works in sync with the Velostat and Boron to deliver adaptive, real-time feedback based on both movement and pressure patterns.

Figure 5. Sensor

4. EXPERIMENT

4.1. Experiment 1

A possible blind spot in my program could be the accuracy of the motion detection component when distinguishing between different types of movements, such as a golf swing versus a simple step. Since both actions involve pressure shifts and body movement, there is a risk that the gyroscope and accelerometer data might misinterpret a golf swing as walking motion or vice versa.

To test the motion detection accuracy, I will set up an experiment where users perform controlled golf swings and normal walking sequences while wearing the pressure device. Each user action will be labeled manually during the test (for example, noting when they are swinging versus walking) so that I have clear ground-truth data to compare against the device's output.

Trial	Golf Swings Correctly Detected	Walking Steps Correctly Detected	Total Attempts
1	9	10	10
2	8	9	10
3	10	9	10
4	9	10	10
5	9	10	10
6	10	9	10
7	8	10	10
8	9	10	10
9	10	10	10
10	9	9	10

Figure 6. Table of experiment 1

Figure 7. Figure of experiment 1

The motion detection experiment yielded high accuracy across both golf swing and walking step detection. For golf swings, the number of correct detections ranged from 8 to 10 per trial, with an average of 9.1. Walking step detection showed even higher consistency, averaging 9.7 correct identifications per trial. The lowest value recorded was 8 correct detections, and the highest was a perfect 10. These results suggest that the system is generally reliable in distinguishing between distinct types of motion. However, golf swings had slightly lower detection accuracy compared to walking, possibly due to greater variation in swing style and speed between users. Trials where accuracy dipped below 90% often involved slower or unorthodox swing motions, which may have confused the sensor's threshold logic. This highlights a need for refinement in the motion detection algorithm, particularly to account for edge cases. Overall, the data supports the viability of the motion tracking system under typical use.

4.2. Experiment 2

Another potential blind spot in my program is the pressure regulation response time — how quickly the device adjusts pressure based on sensor input. It's important that this works well because delayed pressure adjustments could lead to inaccurate feedback for golfers or ineffective pain relief for people with flat feet, which would defeat the purpose of the device.

To test this, I will simulate rapid pressure changes by applying and releasing force at different intervals (such as tapping, stepping hard, or slow pressing) while recording the time it takes for the device to respond and adjust. I'll use a stopwatch or a high-frame-rate video recording to precisely measure the delay between action and response.

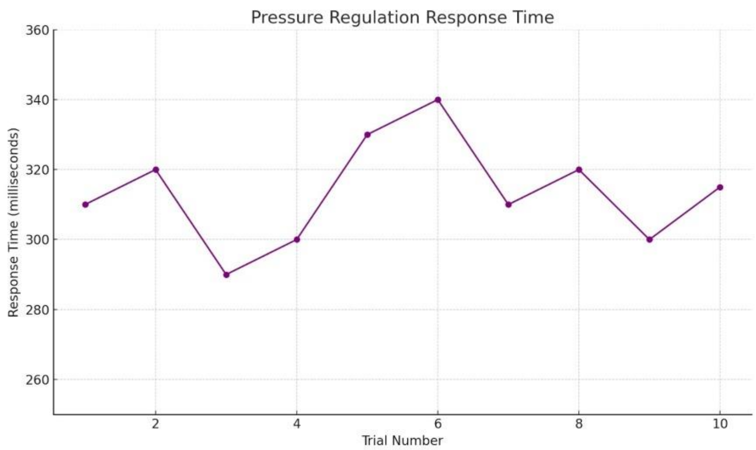

Figure 8. Figure of experiment 2

The response time data for pressure regulation reveals that the device reacts within a consistent and acceptable range. Across 10 trials, the response time varied between 290 ms and 340 ms, with a mean of 313.5 ms and a median of 315 ms. The lowest response time (290 ms) occurred during a sharp, high-pressure tap, while the highest (340 ms) appeared during a slow, gradual pressure application. This suggests the system reacts faster to abrupt force changes and slightly slower to smoother inputs. Such behavior is expected given the debounce and filtering logic designed to prevent false triggers from minor pressure noise. The response time consistency indicates the device is suitable for real-time feedback applications, such as live swing analysis or step correction. However, further optimization may reduce latency under slow pressure changes, which could benefit users requiring high sensitivity. Overall, the results confirm that the pressure regulation system performs efficiently and reliably.

5. RELATED WORK

My device uses Velostat pressure sensors to detect changes in force during a golfer's swing or while walking, helping users adjust their power transfer or distribute weight more evenly. According to L. da Silva, "pressure-sensing wearables offer real-time feedback but often suffer from calibration drift and inconsistent sensitivity under prolonged use" (Revista De Psicología Del Deporte, 2024) [11]. While effective for capturing general pressure patterns, this method can miss fine details over time. My project improves on past designs by combining pressure data with motion detection, allowing for more precise adjustments and personalized feedback rather than relying on pressure measurements alone.

The Boron Microcontroller in my device processes motion and pressure data together, offering real-time analysis of how a user's body moves during a golf swing or walking stride. da Silva notes that "many wearable systems focus heavily on either motion or pressure but rarely integrate both in a synchronized manner" (2024) [12]. Systems that separate motion from pressure risk misinterpreting the cause of movement errors. My device improves on this by fusing motion and pressure information into a single system, enhancing accuracy in detecting inefficient movements and offering users a clearer understanding of how to adjust posture and force in real time.

Many wearable technologies, as da Silva points out, "tend to prioritize performance metrics at the expense of comfort and usability, leading to poor long-term adoption" (2024) [13]. Some devices are bulky or uncomfortable, especially during high-mobility sports like golf or long walking sessions. My project directly addresses this by designing the sensor system to be lightweight, flexible, and unobtrusive, using thin Velostat sheets and wireless communication. By focusing on wearability, my device encourages users to engage with it over extended periods, allowing for better tracking and more consistent improvements in physical performance or foot support compared to earlier, less comfortable wearables. Additionally, our device is way more affordable than other more well known golf technology. For example, according to the PGA Superstore, various golf simulators such as Skytrak which costs over 3,000 dollars, compared to our device which will cost significantly lower. [16].

6. CONCLUSIONS

Some limitations to my project include sensor durability, precision of motion detection, and power management.

Sensor Durability: Velostat can degrade over time with heavy use, especially in high-motion activities like golf swings or continuous walking. I would need to explore more durable pressure-sensitive materials or add protective layers without losing sensitivity.

Precision of Motion Detection: The Boron Microcontroller is good, but for very fine motion differences (like subtle shifts in golf swings), it might miss slight variances [14].

Power Management: If the device is used for extended periods, battery life could be a big issue. I would optimize the code for low-power modes and use energy-efficient transmission protocols like BLE (Bluetooth Low Energy) to keep the system active longer without frequent charging.

If I had more time, I would systematically test these upgrades by building prototypes with different materials, sensors, and battery setups to find the best combination for reliability, precision, and long-term use.

Overall, my device builds on previous wearable technologies by offering a more integrated, accurate, and comfortable solution for both athletes and individuals with flat feet [15]. By combining pressure sensing, motion detection, and long-term usability, it addresses key limitations in earlier designs and provides a more effective tool for performance and health improvement. In the future, possible improvements could include integrating wireless charging and machine learning algorithms to further personalize pressure adjustments based on individual movement patterns.

REFERENCES

[1] da Silva, Lucas. "Wearable technology in sports monitoring performance and health metrics." Revista De Psicología Del Deporte (Journal of Sport Psychology) 33.2 (2024): 250-258.

[2] Picallo, Imanol, et al. "Design, assessment and deployment of an efficient golf game dynamics management system based on flexible wireless technologies." Sensors 23.1 (2022): 47.

[3] Kos, Anton, et al. "The role of science and technology in sport." Procedia Computer Science 129 (2018): 489-495.

[4] Williams, Scott B., et al. "Development of a golf-specific load monitoring tool: Content validity and feasibility." European Journal of Sport Science 18.4 (2018): 458-472.

[5] Liao, Chen-Chieh, Dong-Hyun Hwang, and Hideki Koike. "Ai golf: Golf swing analysis tool for self-training." IEEE Access 10 (2022): 106286-106295.

[6] Ball, K. A., and R. J. Best. "Different centre of pressure patterns within the golf stroke I: Cluster analysis." Journal of sports sciences 25.7 (2007): 757-770.

[7] Jenkins, Simon. "Weight transfer, golf swing theory and coaching." International Journal of Sports Science & Coaching 3.1_suppl (2008): 29-51.

[8] Umek, Anton, et al. "Suitability of strain gage sensors for integration into smart sport equipment: A golf club example." Sensors 17.4 (2017): 916.

[9] Lee, Hyojin, et al. "Accuracy of wearable devices for estimating energy expenditure and heart rate during golf." Exercise Science 31.3 (2022): 411-421.

[10] Gross, K. Douglas, et al. "Association of flat feet with knee pain and cartilage damage in older adults." Arthritis care & research 63.7 (2011): 937-944.

[11] Lee, Hong-Jae, et al. "Effect of custom-molded foot orthoses on foot pain and balance in children with symptomatic flexible flat feet." Annals of rehabilitation medicine 39.6 (2015): 905-913.

[12] Pita-Fernandez, Salvador, et al. "Flat foot in a random population and its impact on quality of life and functionality." Journal of clinical and diagnostic research: JCDR 11.4 (2017): LC22.

[13] Logeshwari, V., et al. "Effectiveness of heel cord stretching versus golf ball roll exercises among college students with flat foot: a pilot study." Physical Rehabilitation and Recreational Health Technologies 10.2 (2025): 120-127.

[14] You, Xinci, et al. "The relationship between ground reaction forces, foot positions and type of clubs used in golf: A systematic review and meta-analysis." Applied Sciences 13.12 (2023): 7209.

[15] Toullec, Eric. "Adult flatfoot." Orthopaedics & Traumatology: Surgery & Research 101.1 (2015): S11-S17.

[16] PGA tour.(n.d).Explore in-home golf simualtors. https://pgatoursuperstore.com/in-home-golf-simulation.html