A Wearable Technology for Torticollis Treatment: A Novel Device with Head Tilt Detection Using an MPU6050 Gyroscope and Accelerometer, Vibrator Motor, and Flutter-Based iOS and Android Mobile Application

Suchita Srinivasan

Abstract

Torticollis, or "twisted neck," is characterized by abnormal cervical rotation induced by genetic or acquired etiologies. One form of the condition, congenital torticollis, is present from birth, with an incidence rate of one in 250 newborns. Conversely, acquired torticollis may emerge at any stage in life, with 90% of individuals experiencing at least one episode during their lifetime. If left untreated, torticollis may evolve into detrimental ailments such as spinal misalignment.

The research strives to design a practical and feasible torticollis treatment device to detect and mitigate the head tilt caused by torticollis. The earpiece device, inspired by auditory prosthetics, is engineered to gauge the patient's head tilt and alert them via minor vibrations if exceeding a predefined threshold. Complementing the physical earpiece component, the mobile application was developed to register and authenticate the patient, or in other words, create their account. It also logs the number of times the alarm was triggered daily. Analysis of the wearable technology revealed the application's efficacy in progressively decreasing head tilt and alert frequency, thereby reducing the possibility of prospective medical ailments and conditions.

Integral technologies utilized include Arduino technologies for the hardware, the Flutter framework and Dart language for the mobile application, and the Firebase Database to store and authenticate user data. The Bluetooth communication protocol was pivotal in connecting and functionalizing the hardware device and the app.

Keywords: **torticollis treatment, head tilt detection, and wearable technology**

Introduction

Torticollis, commonly known as "twisted neck," is a condition distinguished by anomalous head tilting due to the contraction of cervical musculature. This condition may emerge in congenital or acquired forms (Cunha et al., 2023). Congenital torticollis typically arises due to genetic factors, muscle injury during childbirth, or abnormal fetal positioning, thus manifesting shortly postpartum. With an incidence of one in 250 newborns and a gender prevalence ratio of three females to two males, torticollis is among the more prevalent congenital orthopedic conditions (Gundrathi et al., 2024). Acquired torticollis may originate from infections, trauma, and skeletal abnormalities (Gundrathi et al., 2024). It is estimated that 90% of individuals will experience at least one episode of acquired torticollis during their lifetime due to the abovementioned reasons (Cunha et al., 2023).

Current treatments, such as physical therapy and neck braces, have limitations due to the frequency of sessions and the discomfort of wearing visible braces, which can affect self-esteem (Gundrathi et al.). These challenges highlight the need for a more practical, discreet solution.

This research aims to develop an innovative head tilt alerting device to address these issues. The device will include an MPU6050 gyroscope and accelerometer, a vibrator motor, and a mobile app for iOS and Android built with Flutter. The final prototype aims to reduce head tilting in torticollis patients while improving comfort and confidence.

Methods

The final hardware was designed using Arduino technologies, while the iOS and Android mobile application was built using the Flutter Framework. The MPU6050 sensor within the hardware device calculates the user's head tilt, and the vibration motor delivers alerts (Figure 1). Flutter's cross-platform framework allows a single codebase that minimizes platform issues, while Dart is utilized for both UI and backend (Figure 2). Firebase Authentication and Cloud Firestore handle user authentication and data management. Firebase Authentication oversees account creation and security, implementing email and password methods for sign-in and incorporating security measures such as email verification and password complexity requirements. Cloud Firestore managed storage and retrieval of device-related data.

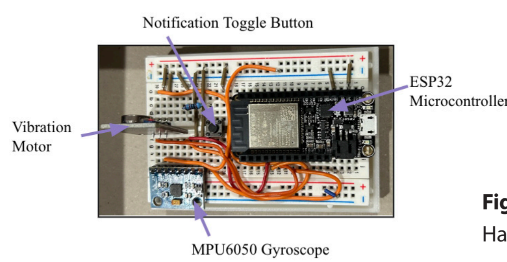

Fig. 1. (Prototype two) Hardware device

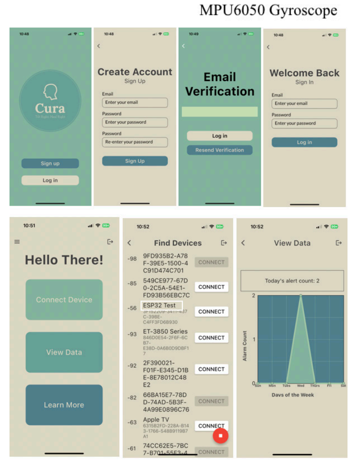

Fig. 2. iOS and Android mobile app screens

Prototype One

The research design progressed through two iterative prototypes, each refining the preliminary concept. The initial prototype utilized dual hardware devices: an earpiece that measured the patient's head tilt and transmitted data to a wearable bracelet via Bluetooth protocol. The earpiece diagram illustrates the ESP32 microcontroller, capable of Bluetooth communications, connected to a button for calibrating head tilt and the MPU6050 sensor, which precisely measures the patient's head tilt (Figure 3). Using a vibration motor and LED, the wearable bracelet provides vibratory alerts to indicate the patient's irregular head tilts (Figure 4).

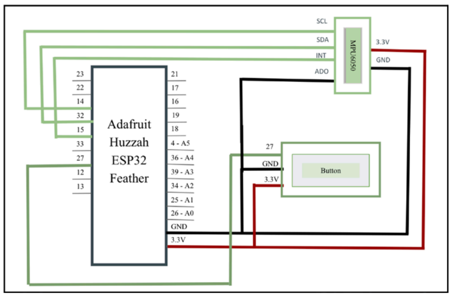

Fig. 3. Hardware schematic of the earpiece device, consisting of an ESP32 microcontroller wired to a button and MPU6050.

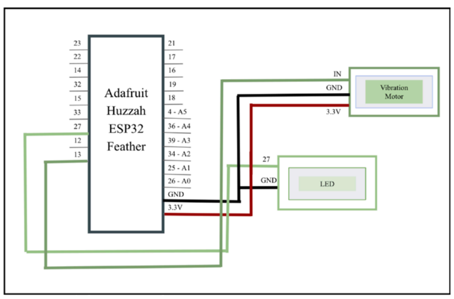

Fig. 4. Hardware schematic of the wearable bracelet consisting of an ESP32 microcontroller wired to the LED and vibration motor.

The mobile application associated with the primary prototype was designed to authenticate user accounts, log data, and configure device parameters such as tilt thresholds and alert frequency. With this prototype design, the earpiece and mobile application functioned as central and peripheral devices, while the wearable bracelet operated exclusively as a peripheral device (Figure 5).

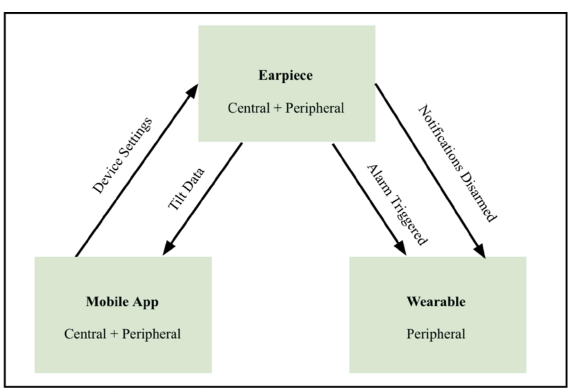

Fig. 5. Bluetooth diagram depicting information exchange from peripheral and central devices.

Prototype Two

Prototype two addressed Bluetooth communication limitations found in prototype one. In prototype one, the initial performance of the Espressif ESP-Now protocol for the hardware devices proved incompatible with mobile applications, prompting a transition to the Bluetooth Low Energy (BLE) protocol. Additionally, the inability of the ESP32 hardware device to behave simultaneously as a peripheral and central device resulted in the redesign. In prototype two, the earpiece was configured as the central device, while the mobile application operated as the peripheral (Figure 6).

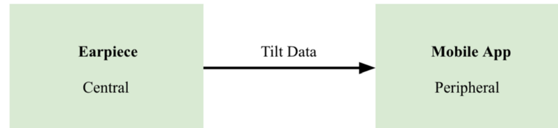

Fig. 6. (Prototype two) Bluetooth diagram depicting information exchange from earpiece to mobile app.

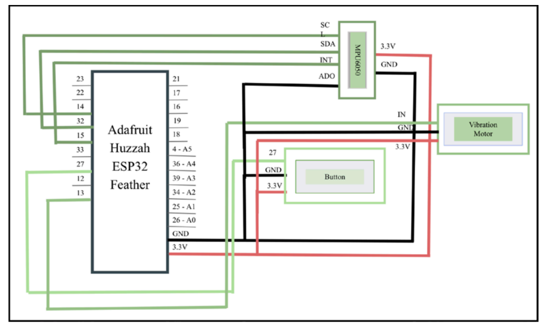

Fig. 7. (Prototype two) Hardware schematic representation of an earpiece device consisting of an ESP32 microcontroller wired to a button, vibration motor, and MPU6050.

The revised product design allowed the earpiece to measure head tilts and deliver vibratory alerts while the mobile application facilitated user authentication and displayed weekly alert data. The ESP32 connects to the MPU6050 sensor to measure head tilt. A button calibrates the tilt threshold; if the threshold is exceeded, the vibration motor alerts the user (Figure 7). The shift to prototype two effectively reduced the number of hardware components involved and decreased the components' price from $58.91 to $36.59.

Results

The final product will be shaped as an earpiece, though the prototype was tested by fastening it securely over the experimenter's head, a torticollis patient. Performance was monitored for one hour daily, with testing each evening to keep daily routines constant and minimize impact on results. The study tracked alarm triggers directly correlating with abnormal head tilt (Figure 8).

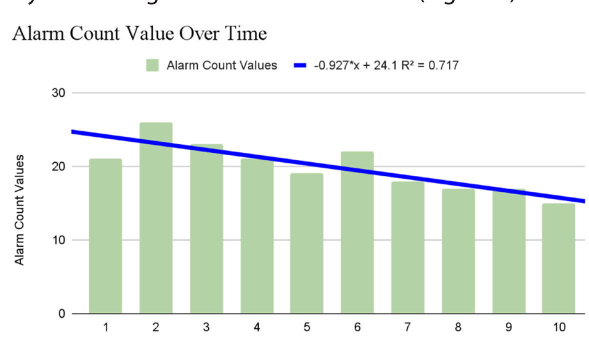

Fig. 8. Graphical depiction of testing conducted and number of times alarm triggered each day.

Day	Alarm Count Values
1	21
2	26
3	23
4	21
5	19
6	22
7	18
8	17
9	17
10	15

Table 1. Tabular representation of testing conducted and number of times alarm triggered each day.

Statistical analysis shows an average daily alarm count of 19.9, with a median of 20. The best-fit line equation $y=–0.927x+24.1y = -0.927x + 24.1y=–0.927x+24.1$ describes a decrease of about one alarm per day. The R^2 value of 0.717, between 0.5 and 1.0, proves statistical significance. The interquartile range (IQR) is 5, with Q1 at 17 and Q3 at 22, calculated using Tukey's Hinges method. Outlier analysis, based on (Q1 - 1.5*IQR) and (Q3 + 1.5*IQR), set the boundaries at 9.5 and 29.5, with no outliers detected.

Discussion

Despite fluctuations, the data trend supports the device's efficacy in detecting abnormal head tilts. An initial alarm spike suggests the experimenter's device awareness, prompting cautious behavior. Accuracy improved as the experimenter returned to typical habits. While results confirm the device's functionality, long-term improvement requires extended wear.

Previous research on the efficacy of bracing proves that collars such as the TOT Collar positively affected infants when worn for seven weeks to six months (Zahid & Asif, 2022). This discovery is again supported by prior studies stating that if progress is observed following seven weeks of neck brace use, the brace may be prescribed for only nightly use (Kaur, 2020). As the torticollis device created functions similarly to bracing by preventing irregular head tilting, similar results on effectiveness would be found with extensive wear.

Conclusion

Built using Arduino and Flutter technologies, the device utilizes the MPU6050 and the vibration motor to alert patients if their head is tilted beyond a threshold. With an R^2 value of 0.717 suggesting a strong correlation between the device functionality and reducing the head tilt, the device has proven beneficial in lessening the impact of torticollis.

Some limitations in the design include the lack of two-way Bluetooth communications between the app and the device, which, if implemented, allows for more personal settings. Thus, future considerations include incorporating tilt angle and alert frequency settings within the app and daily in-app notifications about physical therapy reminders to further support the patient's progress. This enhancement is reinforced by prior research, which found that 2018 CPG physical therapy methods increased neck range of motion for congenital muscular torticollis (Castilla et al., 2023). Lastly, the product will undergo extensive testing from medical experts and patient trials to receive feedback and effectiveness for widespread use.

References

Castilla, A., Gonzalez, M., Kysh, L., & Sargent, B. (2023, April). Informing the physical therapy management of congenital muscular torticollis clinical practice guideline: a systematic review". *Pediatric Physical Therapy*. https://journals.lww.com/pedpt/fulltext/2023/04000/Informing_the_Physical_Therapy_Management_of.3.aspx

Cunha, B., Tadi, P., & Bragg, B. N. (2023, August 8). Torticollis. *StatPearls* [Internet] https://www.ncbi.nlm.nih.gov/books/NBK539857/#:~:text=oblique%2C%20or%20torsio n.-,Torticollis%20is%20a%20common%20diagnosis%2C%20and%20estimates%20are%20that%2090,causes%20such%20as%20brain%20injury

Gundrathi, J., Cunha, B., Tiwari, V., & Mendez, M. D. (2024, March 20). Congenital torticollis. *StatPearls* [Internet] https://www.ncbi.nlm.nih.gov/books/NBK549778/

Kaur, S. (2020, February). Congenital torticollis and its physiotherapy management *International journal of health sciences and research*.https://d1wqtxts1xzle7.cloudfront.net/64117452/15-libre.pdf?1596781209=&response-co ntent-disposition=inline%3B+filename%3DCongenital_Torticollis_and_Its_Physiothe.pd f&Expires=1723991176&Signature=BN1KZVgPFWjGbZRL~tYPYANKf-Ni7XoEW1Se573sl~wU4fvs7cgZzmf~GuECLopca1xPMUhP3OCbXVKbgLwoiy-Ox3WoZzyQmCrD6l3xme~aAj1HY5ihRLxFTCL2hYTwR-BK-erpkfH3VlrzI7nM0x-AkkAaZlpiVkuCtCYAIUzNtqaVQ~DbQfo~TRUh3SiU13c-2QLFx7LPuLWvhXM-LSDZIkOgWK2FFRGFwNvwLm-dJg1Un~JHcEQw6EMWJC3x2M-SdU0~1k9U-8aehkiUG4NEBFd3ZJxk4oUM88-asOZG1V1Fjp-FM6~NP4Nnuq8Qlz3cAhE-hH18W4Ny1c5rlV7wLa3w__&Key-Pair-Id= APKAJLOHF5GGSLRBV4ZA

That Project (2019, Oct 6). *ESP32 | FLUTTER | BLE - MPU6050, Rotate your 3D object in the app*. [Video]. YouTube. https://www.youtube.com/watch?v=FMZO4UTVZBk

DroneBot Workshop. (2020, November 3). *[FLUTTER] control arduino and bluetooth module*. [Video]. htpps://www.youtube.com/watch?v=Ofm1oyJZlmQ&t=156s

DroneBot Workshop. (2022, April 3). *ESP-NOW - Peer to peer ESP32 network*. [Video]. htpps://www.youtube.com/watch?v=bEKjCDDUPaU

Zahid, T., & Asif, I. (2022, September). A review of efficacy of various cervical orthoses in congenital muscular torticollis. *Asia Pacific Journal of Allied Health Sciences*, 5(2). https://research.lpubatangas.edu.ph/wp-content/uploads/2022/06/6-AP-JAHS-2020-01.pdf