

Impact Absorbing And Alerting (iAAA) Wearable Headband

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Abstract

Alarming CDC statistics highlight Traumatic Brain Injuries (TBIs) resulting from falls as the leading cause of mortality in older individuals (≥ 65) and those with neurodegenerative diseases. We announce a significant advancement in mitigating the impact on the head during falls and triggering an emergency alert through a high-tech headband. Our approach involved consultations with healthcare professionals, including physicians, nurses, and dedicated caregivers experienced in caring for individuals prone to falls. Their feedback, as well as information from supplementary external research, led to the invention of the *Impact Absorbing And Alerting (iAAA)* headband. The *iAAA* consists of lightweight, impact-absorbing foam materials and integrated electronic components. To evaluate its effectiveness, we conducted rigorous testing using a "Century Martial Arts Bob Body" dummy, weighing 37 pounds, as our test subject. The headband was securely affixed to Bob's head, and we subjected him to falls from various heights and angles. After preliminary testing on a BOB dummy, the *iAAA* band demonstrated effective impact absorption and alerting. In summary, our future experiments will involve the use of Anthropomorphic Test Dummies (ATDs) to further assess the performance of the *iAAA* band. As an enhancement to the headband, we have incorporated a camera and a sound sensor to detect a fall and alert caregivers. Using Raspberry Pi technology, the headband not only triggers an alert, but also sends images of the fall victim's surrounding to designated caregivers. This development represents a significant leap forward in addressing the critical issue of fall-related injuries in the aging population and those with neurodegenerative diseases, offering a comprehensive solution that combines impact alleviation and advanced alert systems.

Keywords: *iAAA*, Headband, Head Protection, Elderly Care

Introduction

Accidental falls are one of the most common causes of unintentional injury deaths worldwide, annually claiming the lives of 684,000 individuals, according to the World Health Organization (WHO). A journal published by the CDC stated that unintentional falls are the leading cause of injury and deaths among adults aged ≥ 65 years in the United States (Kakara, 2023). In 2020, 14 million older adults in the United States reported falling and 36,500 fall deaths occurred among older adults. Fall-related injuries are also common among individuals with neurodegenerative disorders, as patients with stroke were six times, and patients with PD [Parkinson's Disease] five times, more likely to suffer falls than healthy controls, reported a journal published by the National Center for Biotechnology Information (Homan, 2013).

Most fall deaths among older adults are caused by Traumatic Brain Injury (TBI), and the national rate of TBI-related fatalities among older adults has increased by 17% from 2008 to 2017 (Kakara, 2023; Peterson, 2020). In addition, a lab at Arizona State University predicted that we could expect 7 fall deaths per hour by 2030, a stark increase from the current rate of 4 fall deaths per hour (ASU, 2024). Further, ASU reports that the annual medical costs attributed to senior falls are \$50 billion in the US alone. Diving deeper, we did market research on protective headwear products. We found that these products limit the ability to absorb the impact

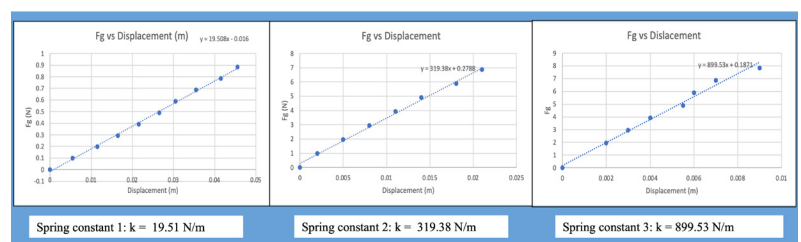
on the head and have no alerting features, delaying medical attention and worsening existing injuries (Martel, 2021; Haag, 2024). In contrast, existing alert systems, like Life Alert™, do not absorb the impact of a fall to the head and require a user to activate the alert manually, which will not work if a user is unconscious.

In our research, we developed a preventive mechanism for TBIs by mitigating impact on the head and immediately alerting caregivers in the vicinity and far away in the event of a fall before the damage to the head worsens. Our invention will minimize future head injuries and fatalities due to falls and reduce the annual medical costs for falls.

Methods

We first interviewed doctors, nurses, elderly home nurses, hospice care nurses, and individuals caring for family members with PD. They all told us a band that would absorb the impact and alert caregivers would be ideal. Then, we concentrated on the impact absorption feature of the band. We acquired a strip of lightweight foam material present in face shields due to its shock-absorbing feature and comfortability and cut out a strip to be worn around the head. We also decided to embed springs in the band to strengthen the impact absorption. In order to find an effective spring to use for the band, we tested several types of springs for the most optimal spring constant (k) value. All three springs were made of zinc plated

Fig. 1. Shows applied Force (F_g) vs. Displacement graphs for three different springs. We picked the spring with $k = 319.38$ N/m for our head band.



steel, and their diameters were each around 5 mm. (As shown in Fig.1, using Hooke's law ($F = -kx$), where F is the force, k is the spring constant, and x is the spring's displacement), we found the k values of 19.51 N/m, 319.38 N/m, and 899.53 N/m. The spring constant of 19.51 N/m would've compressed easily on impact and lead to minimum impact absorption, while the spring constant of 899.53 N/m would be too stiff and damage the band upon impact. We chose the spring with a k value, 319.38 N/m, because it supported optimal impact absorption during a fall.

Using a soldering rod, we drilled equally spaced holes in the band and embedded the springs into each hole, as shown in Fig. 2 [A & B]. They were arranged in parallel so that they absorb the impact better. (OpenStax, 2015). We then inserted a lightweight buzzer (DC 3-24V Electronic Buzzer Alarm Sounder of 100 dB) and disk battery into the band and connected them in series, as shown in Fig [3]. We made sure those components aligned with the ear when the band was worn around the head.

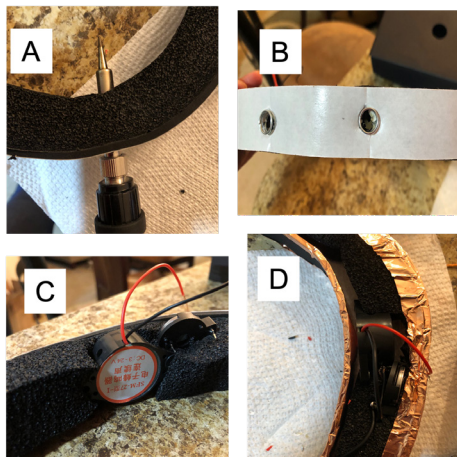


Fig. 2. shows the process of implementing the springs and buzzer alerting system onto the iAAA band.

In order to complete the circuit as shown in Fig [3], we wrapped the top and the bottom of the band using a conductive copper foil as shown in Fig.2 [C & D]. Using a rubber O-ring around 2 mm thick, we made a gap between the spring and the conductive copper layer which acted as a switch, preventing the headband activating due to minor impacts (e.g., leaning on a chair), and the buzzer gets activated when impact occurs, as shown Fig. 3 [B].

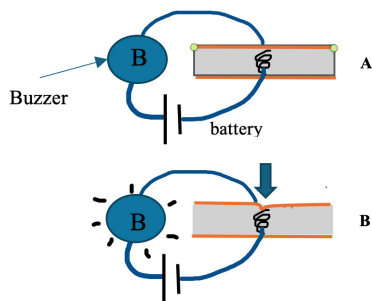


Fig. 3. (A) shows the Head band with the embedded spring - the circuit is open. Fig[3B] illustrates how the circuit gets completed when an impact occurs, and the buzzer is activated.

Results and Further Modifications

Upon completing our first band, we fitted it around the head of a BOB martial arts dummy, and staged falls from various heights, angles, and locations around the house (Myers, R. 2022). Table 1 shows our observations.

Height (H) in cm	Face Down Fall	Backward Fall	Sideways
40	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	No impact to head blocked by the shoulder
43	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	No impact to head blocked by the shoulder
48	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	No impact to head blocked by the shoulder
53	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	Absorbed the impact and the buzzer noise was heard from up to 20 feet away.	No impact to head blocked by the shoulder

Table 1. The table shows our observations with the iAAA band on Bob. The impacts on both backward and Face forward falls were successfully absorbed as the band returned to the normal state. Buzzer alert was tested from 2 bedrooms and basement.

As shown in the table, for Face Down and Backwards falls, the band was compressed, the buzzer played the noise, and the band then returned to its original form. After the initial testing, we received feedback from potential users. One concern they had was the range of the buzzer sound and how a caregiver would be alerted if they were away from home. As a result, we decided to iterate the product to text messages to a caregiver, alerting them that a fall had occurred. We used few additional components: a Raspberry Pi (a small, single board computer the size of a credit card), a pi-camera, a sound sensor, and a pi-battery. Figure 4 shows the final iAAA band mounted on a 3D printed support on BOB.



Fig. 4. shows the iAAA band on BOB, one is with the beanie to cover the band

We programmed the Raspberry Pi using the Python programming language to work in tandem with the existing buzzer system (Karunaratne, 2024). When the sound sensor detects the buzzer noise (during a fall), the Pi camera takes a picture of the surroundings, puts it in a Google Drive with the incident timestamp (file name, formatted in military style), as shown in Fig. 6 and sends the image with a customizable message, "check on grandma," to caregivers.



Fig. 5. shows the iAAA band tested at different locations, inside and outside. The camera takes a surrounding picture and directs to the caregiver. First responders can find the victim easily and medical experts can evaluate the patient knowing where the fall had occurred. A bedroom, B kitchen, C bathroom, D outside in the driveway.

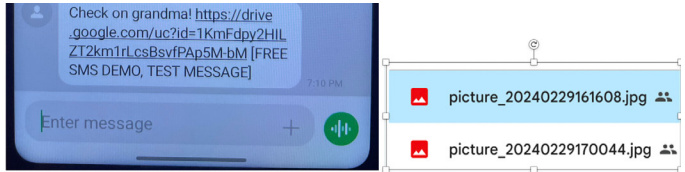


Fig. 6. shows the text message as received on the phone, and the link directs to the images, which have been uploaded onto google drive. The file name gives the timestamp of the fall in military style.

Discussion

In the event of a fall and hitting the head, the iAAA band successfully absorbs the impact on the head, emits a sound from the buzzer, detects the sound and captures a photo of the surrounding, precisely records the time of the fall, and sends an SMS to caregivers. Some available alerting products do not absorb the impact to the head, and alerting is done manually, but iAAA band does the alerting job automatically. On the other hand, available products with impact-absorbing features, like football head guards, do not have a built-in alerting system. We believe iAAA has a great potential as it has both features, absorbing the impact and alerting, already built in.

Conclusion

In conclusion, the novel absorption feature in the iAAA band, combining springs and shock-absorbing foam, will help prevent head injuries or TBIs among fall victims. This is an improvement in the market, compared to our observations of other products, as shown in Table 2.

Product Name	Impact Absorbing Ability	Alerting Ability	Cost
iAAA+	Can effectively absorb the impact of a fall.	Can alert those in vicinity of the fall (buzzer system) and those far away (raspberry pi alert)	\$35.00
Life Alert	Has no impact absorbing ability	Requires the user to be conscious after a fall to press a button or call for help. In falls where there is impact to the head (usually the most dangerous type of fall), a fall victim is rendered unconscious.	First-year cost of \$796.40. (LifeAlert, 2024) Can cost up to \$49.95 to \$89.95 per month.
Thick Soft Protective Helmet for Elderly Youth Adult Sizing	Has some impact absorbing ability, seems to use Styrofoam as their impact absorbing material.	Has no alerting ability in place.	\$29.40

Table 2. Compares the impact absorbing ability, alerting ability, and cost of impact absorbing and/or alerting products in the market to the iAAA+ band.

By immediately alerting caregivers, the iAAA band will prevent a worsening of the fall victims’ condition and the timestamps will help them during treatments. For future research, we will focus on making the band more comfortable and fashionable for users, as comfort and fashion are valued by all.

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