Introduction

1. **Mild Traumatic Brain Injury (mTBI)** isn’ t easily noticed due to the lack of symptoms, and medical research has shown that it may have long term effects on the brain [1] .
2. While direct external trauma to the head, such as a brain injury caused from a car crash, may induce mTBI, **Whiplash Injury** [2] may also lead to mTBI due to the abrupt acceleration and deceleration of the brain.
3. **Head Injury Criterion (HIC)** [3] is an index used to represent the levels of head injury. Current research on HIC is mainly focused on the single head impact model. However, a standard is needed to determine the severity head injuries caused by multiple head impacts.

Objectives

1. Develop a **wearable mTBI warning system** by defining the HIC threshold based on the Closed Head Impact Model of Engineered Rotational Acceleration (CHIMERA)〔Fig. **1**〕.
2. Analyze the **potential risk of mTBI** while doing common daily activities, such as dancing or riding a roller coaster.
3. Develop a **continuous head impact simulator** to analyze continuous motion.

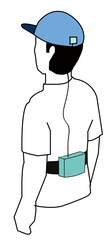

Fig. 1. Wearable mTBI Warning Device

Methods

Definition of mTBI based on HIC threshold value

1. Head Injury Criterion (HIC) is used to represent the levels of head injury. Based on the data measuring the acceleration and deceleration of the brain and time intervals of the motion, which is defined as 15 ms or 36 ms, HIC can be obtained by using formula 1.

$$HIC = \left\{\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a \cdot \Delta t\right]^{2.5} (t_2 - t_1)\right\} \qquad (1)$$

2. Current medical research on head injury is mainly based on CHIMERA, an experimental model that can simulate a single impact on the mouse’ s head by an air-powered impact module〔Fig. **2**〕.
3. CHIMERA includes a high-speed camera to record and measure the impact on the mouse’ s head. This data will be compared to the data from the injury of the mouse’s brain to determine the severity.
4. When HIC >= 51, a head injury in the mouse’s brain can be observed〔Fig. **3**〕. Thus, the occurrence of mTBI has been given a threshold of HIC = 51 in this study, which is equivalent to 29G of impact force to the head.

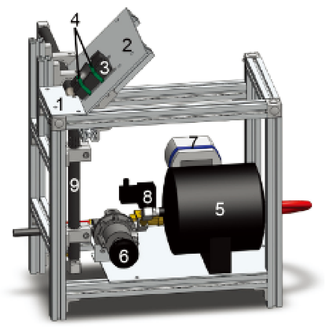

Fig. 2. Closed-Head Impact Model of Engineered Rotational Acceleration [4] .

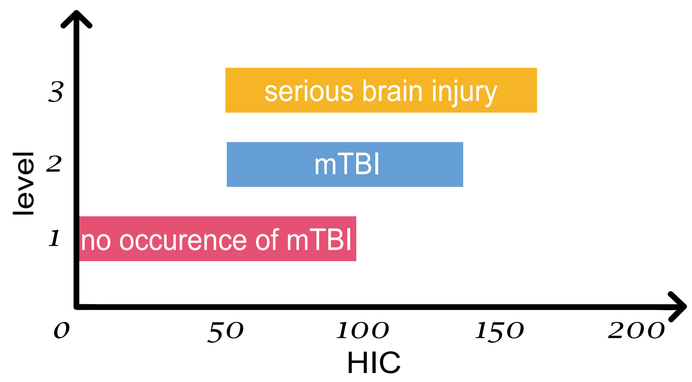

Fig. 3. HIC value and head injury examination through dissections of the brain. According to the degree of injury, the vertical axis is labeled: no occurence of brain injury, mTBI, serious brain injury, from bottom to the top [5] .

Wearable mTBI warning device

1. Figure 4 shows the prototype of the wearable mTBI warning device.
2. The proposed system consists an MCU and an accelerometers, which is shown on Figure 5.
3. The workflow of the wearable mTBI warning device is shown on Figure 6.

Fig. 4. Prototype of the wearable mTBI warning system

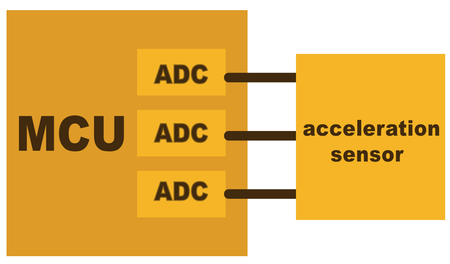

Fig. 5. Block diagram of the warning device

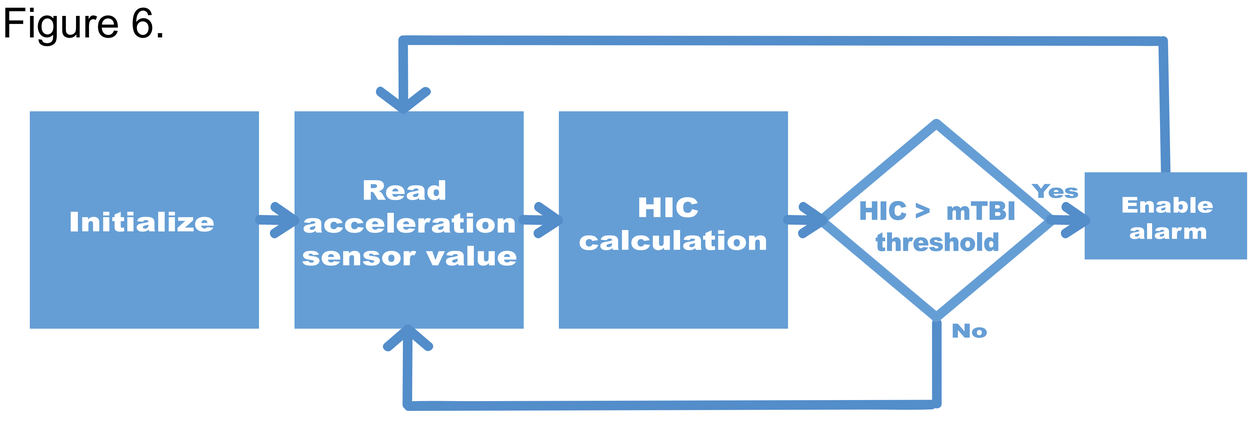

Fig. 6. System software flowchart

Measurement of acceleration

1. To verify whether the sampling rates of my warning device are high enough, I used the Fast Fourier transform (FFT) to transfer the signal from the time domain to frequency domain.
2. Collect the value for x, y, z components simultaneously and use formula 2 to achieve the final result. The value calculated in equation 2 will be used for the HIC calculation.

$$|\vec{a}| = \sqrt{{a_x}^2 + {a_y}^2 + {a_z}^2} \qquad (2)$$

Implementation of continuous head impact simulator

1. Current CHIMERA technology relies on air-pressured impacts, which are not able to generate continuous patterns of collisions. To solve this problem, we modified the model and introduced our system using an electromagnetic module to generate impacts. Figure 7 is the system block diagram of the proposed continuous head-impact simulator. This simulator includes an electromagnetic impact module (a), a controller (b) and an impact platform (c).
2. Formula 3 implies that it is able to manipulate the impact force of our model by simply changing the time interval of the input signal.

$$\mathrm{F} \times S = P \times t \qquad (3)$$

3. By using the correlation formula, which implies the relevance between a known data set and the set of newly inputted data, the critical value of brain injuries can be defined.

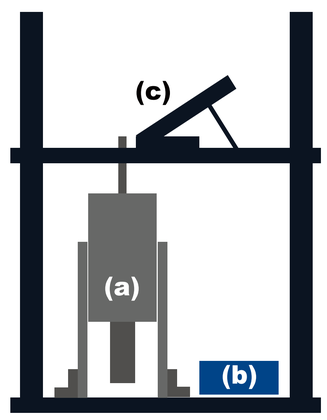

Fig. 7. Continuous head impact simulator