

# Research of drowning autonomous rescue product based on swallowing monitoring

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Abstract. To find a better self-rescue way for sudden drowning swimmers through the redesign of drowning self-rescue products. Based on the self-rescue needs of drowning patients and the design and evaluation criteria of product ergonomics, the situation analysis method was used to record, evaluate and summarize the physiological signs and behavioral characteristics of drowning patients. The causes and rules of changes in the characteristic physiological signs of "swallowing" of drowning patients were deeply studied, and the ways and methods of obtaining information about "swallowing" were explored. Experiments were conducted to verify the feasibility of the swallowing monitoring technology in the water environment. The results showed that there were significant differences in physiological signs of "swallowing" between drowning people and normal swimmers due to the behavior of "bucking", which were accurately identified by swallowing monitoring technology through the audio signals generated by the throat. It is proved that swallowing monitoring technology can be effectively applied to the design of drowning self-rescue products, which can improve the success rate of drowning self-rescue and reduce the occurrence of drowning accidents.

Keywords: Product design, autonomous rescue, swallowing monitoring, drown

# 1 Introduction

According to a report released by the World Health Organization in 2020, more than 372,000 people die from drowning every year. Drowning accidents bring great harm to the families involved, as well as great losses to the society.

A variety of existing drowning rescue products play a positive role in determining drowning. Huang Jiayin et al. used heart rate monitoring combined with immersion time to determine whether the user was drowning, and uploaded the location of the drowning victim using a wireless positioning system[1]. Qiang Xizhu et al. discussed the connection between GPS positioning technology and acoustic technology, and developed an alarm positioning system that can quickly determine the location of drowning victims and inform lifeguards in time [2]. Fu Shipei et al. used the chip sensing

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R. Appleby et al. (eds.), *Proceedings of the 2nd International Conference on Intelligent Design and Innovative Technology (ICIDIT 2023)*, Atlantis Highlights in Intelligent Systems 10, https://doi.org/10.2991/978-94-6463-266-8\_8

system to measure the heartbeat and respiration rate, combined with GPS positioning, GSM communication and other modules to design a bathing suit that can quickly obtain the position of drowning victims [3]. In the above studies, researchers effectively judge whether swimmers are drowning according to the regular changes of different physiological signs of the human body, and design a series of products to quickly locate the location of drowning victims, so as to improve the efficiency of targeted rescue for rescuers. But the product design idea of self-rescue has not been proposed yet. Based on the above ideas, this paper explores the design and completes the design practice.

# 2 Analysis of existing drowning rescue products

Today, swimmers typically use two types of products: water rescue products such as life jackets and rings, which ensure the user stays afloat. But the product volume is not small enough, will cause certain obstacles to the user's action; The second is wearable products worn on the hand, neck and other parts. This kind of products are small and beautiful, will not affect the normal activities of users, and can provide rescue for users. However, the rescue switch needs to be triggered manually, which increases the difficulty of self-rescue for drowning victims.

In order to solve the above problems, exploring a wearable drowning autonomous rescue product, which can recognize whether the user is drowning and automatically launch rescue when the user is drowning. Its design positioning is as follows:

- 1. The product should be small and light, and will not affect users' normal activities
- 2. The product can monitor human physiological signs in real time to determine whether the user is drowning
- 3. When drowning occurs, the product immediately implements rescue

# 3 Summary of behavioral characteristics and physiological signs of drowning victims

#### 3.1 Analysis of behavioral characteristics of drowning victims

When a drowning accident occurs, the victim initially holds his breath to avoid choking and continues to struggle in an almost upright position. Subsequently, forced respiration due to hypoxia causes water to fill the respiratory tract and alveoli, causing changes in blood osmotic pressure, electrolyte disturbance and tissue damage, and finally respiratory arrest and cardiac arrest. In this process, the drowning person cannot shout out for attention or seek help in other ways; More difficult to overcome panic, and calm to take effective self-rescue measures. Therefore, it is important to wear drowning rescue products that can implement rescue.

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## 3.2 Changes in physical signs of drowning victims

Physiological sign is the pillar to maintain the normal activities of the body. It changes with the external environment and is directly reflected by the corresponding physiological parameters. To measure one or more physiological sign parameters and control the load of human body under a certain level can ensure the safety of human body. In drowning, water gradually fills the respiratory tract and alveoli of the body and causes a lack of oxygen, leading to death by suffocation. In this short few minutes, various physiological sign parameters in human body will cause drastic changes due to hypoxia [4]. The changes of some physiological signs are shown in Table 1.

Physiological sign	Concrete change	Range of variation
Body temperature	Slightly elevated	Small
Heart rate	Rapid heart rate	Large
Blood pressure	Blood pressure rises sharply	Large
Respiration	Rapid respiratory rate	Large
Swallow	Accelerated swallowing fre-	Large
	quency	

Table 1. Changes in physiological signs during drowning

# 4 Application of swallowing monitoring technology in products

### 4.1 Selection of characteristic physiological signs during drowning

In drowning, all the physical signs show a regular trend of change, but not all physiological signs can be used as the characteristic physiological signs of drowning. Body temperature usually remains relatively constant and does not fluctuate beyond the normal range, so body temperature data cannot be used to determine drowning. Due to the influence of gender, age and other factors, there are great differences in the normal values of heart rate and blood pressure in different people. It is difficult to summarize the regular variation range of heart rate and blood pressure applicable to all people, which cannot be used as the characteristic physiological signs of drowning. Devices that can accurately monitor respiration are mostly used in clinical practice, but have not been widely used in daily life [5]. According to the behavioral characteristics of drowning victims, it is inevitable that there will be intermittent "water choking" during drowning, which leads to a significant increase in the frequency of swallowing. Therefore, swallowing can be used as the characteristic physiological signs of drowning for indepth study.

### 4.2 Overview and application of swallowing monitoring techniques

Swallowing is one of the body's most complex physical reflexes, a physical sign that moves food and saliva from the mouth to the digestive system. Most of the studies on

swallowing are limited to the medical field and focus on patients with swallowing disorders. Swallowing monitoring technology is applied in many aspects. It can use microphone, piezoelectric sensor, buckling sensor and other equipment to collect a variety of signals including sound, acceleration, voltage, electromyography, and muscle movement. The content and method of signal acquisition are shown in Table 2.

sensor	Obtain information	Sensor position
Sound sensor	Obtain information	larynx
Myoelectric sensor	Duration and frequency of swallowing	larynx
Buckling sensor	Swallowing movement and duration	larynx
Acceleration signal	Physiological movements of the hyoid	The cartilage of the lar-
	bone	ynx
Pressure sensor	Signal feature analysis	Maxillary mouth
Piezoelectric sensor	Swallowing recognition	larynx

Table 2. The content and manner of the signals obtained

With the development of hardware intelligent technology, most wearable products have physiological parameter monitoring function [6]. The wearable products using the swallowing monitoring technology are mostly directly fitted to the larynx. They are small in size, portable and less complex in information processing, which can bring better practicability. Various physiological information can be collected by combining various kinds of sensors and applied to different fields in different forms.

# 5 Feasibility study of swallowing monitoring technology in water environment

### 5.1 Selection of swallowing monitoring signals in water environment

Swallowing monitoring technology can cooperate with different sensors to obtain different physiological signals. In order to effectively identify the difference between normal swallowing and drowning swallowing, many physiological signals that can be monitored need to be screened. The water environment is complex, so the signal collection equipment needs to be small and simple if the collection content needs to be satisfied. The audio signal can reflect the swallowing duration, frequency and other related information, which can be recognized and collected only by wearing a sensor in the throat. Therefore, the audio signal is selected to judge the swallowing state in the water environment.

### 5.2 Experiment on the feasibility of swallowing monitoring technology

The audio of "choking water" was recorded as a quantitative experiment to simulate the drowning person's "choking water" behavior. In the pool, the radio camera is selected as the sound receiving device, and the mobile phone is selected as the voice device to play the audio of "choking water". The two devices are fixed together, and the audio of

"choking water" is played respectively above and below the water surface to simulate the state of swimmers' activities and immersion in water, and verify the influence of environmental changes on the signal. The two devices are controlled to move regularly up and down the water surface and play the audio of "choking water" to simulate the drowning state and verify the influence of behavior change on the signal. The experimental audio signal diagram is shown in Figure 1.

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Experiment 1	Experiment 2	Experiment 3

Fig. 1. Experiment with track graphics

# 5.3 Experimental result

By comparing the corresponding audio charts of experiment 1 and experiment 2, there is no significant difference between the audio data of experiment 1 and experiment 2. Although the volume changes remain the same, the sound intensity in experiment 2 decreases somewhat. It is concluded that the audio signal changes with the change of the position of the voice, and the swimmer's position can be determined by using the signal characteristics.

Observation experiment 3 corresponds to the audio graph, which is different from experiment 1 and experiment 2. Audio, volume are presented with new characteristics of change. It is concluded that there are obvious differences between the audio signals from the larynx during drowning and the signals from the normal movement, which can be used to judge whether the swimmer is drowning.

Thus, it can be proved that swallowing monitoring technology can detect whether swimmers are drowning by monitoring the audio signal of "choking water".

### 5.4 Product function module design

Based on the experimental results, a wearable drowning self-rescue neck ring was designed for swimmers, which integrates physiological signs monitoring and rescue functions. The monitoring module is a laryngeal liner with built-in audio signal sensor, which can monitor the voice emitted by the user's larynx in real time and judge whether the user is drowning according to the audio signal characteristics. The rescue module is an airbag bin on both sides of the neck ring, which has a disposable liquid carbon dioxide cylinder inside and is connected to a small inflatable air bag folded inside the bin. When the user swims normally, the air bag compartment on both sides is closed.

When the sensor detects an audio signal consistent with "drowning" characteristics and the duration is longer than 6 s, the user is judged to have drowned. The air bag quickly automatically inflates the top cover and lifts the user's head to the top of the water surface to prevent choking again, completing the autonomous rescue.

#### 5.5 Product ergonomics and material analysis

Gender, weight and other factors lead to the differences in the neck circumference of different groups of people. According to the neck circumference data of different groups of people, the size and adjustment range of neck rings are divided into three types, respectively suitable for children, men and women. Specific data are shown in the table 3.

Population cate- gory	Neck circumference size /mm	Neck ring adjustable range /mm
male	310-420.	305-425.
female	270-360.	265-365.
children	240-290.	235-295.

Table 3. Necklace size setting

The sensor used for monitoring audio signals is closely fitted to the larynx. In order to ensure the quality of the collected signals, the sensor fitting is located at the lateral edge of the trachea and below the cricoid cartilage, which is the best position for collecting audio signals [7].

The wearable drowning self-rescue neck ring needs the throat to fit tightly when it is used. Therefore, the comfort of wearing the product should be improved on the premise of realizing the rescue function. Therefore, elastic silicone with anti-slip effect is selected as the material of the neck ring belt. In order to ensure the accuracy of monitoring data, polydimethylsiloxane (PDMS) was selected as the flexible substrate of the sensor, and graphene was selected as the induction material of the flexible sensor, so that the sensor could fit closely with the skin and maintain stable performance and high sensitivity.

### 5.6 Product display

The product rendering display is shown in Figure 2 and 3.



Fig. 2. Product display drawing



Fig. 3. Product display drawing

# 6 Conclusion

Through the investigation and analysis of the behavioral characteristics and physiological signs of drowning victims, it is found that there are obvious differences between drowning victims and normal swimmers in many aspects, among which the physiological signs of "swallowing" are the most characteristic. According to the different audio signals produced by the larynx during "swallowing", swallowing monitoring technology is used to realize the accurate identification of drowning victims. Therefore, a wearable drowning self-rescue neck ring based on swallowing monitoring technology is designed to provide effective autonomous rescue help for drowning patients.

# Acknowledgement

This work was supported in part by the National Natural Science Foundation of China under Grant 62171327 and the Graduate Innovative Fund of Wuhan Institute of Technology (Grant No. CX2022507).

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