

## Rescue devices in the water environments: a systematic review

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### ABSTRACT

Using of rescue devices is necessary to prevent drowning in the water. The purpose of this review was to collect new information regarding different aquatic rescue devices and their functions. We conducted a systematic search using the databases of Science Direct, Google Scholar, PubMed, Elsevier, Springer and Google patent. The keywords that were used in this search were: swimming, beaches, swimming pool, rip current, drowning, rescue, rescue device and lifeguard. This search included all the published papers until 2018. Twenty-three papers were collected and reviewed during this study. In general, the aquatic rescue devices were divided into three groups: 1. Beach devices, 2. Pool devices, 3. Beach and pool devices. Some devices are personal life-saving devices for saving swimmer in water, but others cannot be useful without the presence of lifeguard, therefore we can categorize these devices into two groups: 1. Devices that perform the rescue process without lifeguard assistance, 2. Devices that they cannot rescue swimmer without assistance of lifeguard. There are different kinds of rescue devices, so it is necessary to identify them correctly to choose the best option for the aquatic safety.

**Keywords:** Rescue devices, Beaches, Swimming pool, Drowning.

### Introduction

Swimming is a popular sport among all ages [1] and recommended to patients in eighty percent of the medical cases [2]. In term of risk of injury, water-based exercises do not have great physical stress on the body, as compared to other land-based exercises [3]. Furthermore, swimming has many positive effects on the psychological aspects, for example a psychological study showed that swimming reduces the mental tensions and anxiety while overcoming hopelessness in life [2].

An extra advantage of swimming is being available in many places like swimming pools, beaches, lakes, dams and rivers, but the selected environment to swim should be safe. Despite presence of lifeguards, sometimes people still face staggering events like drowning due to negligence, diseases (e.g. heart attack and epilepsy), stress and rip currents [4-6]. Drowning is a respiratory impairment as a result of being in or under a liquid, which may cause death, with or without morbidity [7]. According to the WHO approximately 0.7% of all the deaths in the world are due to drowning [8]. International Lifesaving Federation (ILS 2007) reported death rates caused by drowning in Brazil (3.5), Finland (3.4), and New Zealand (3.3) have the highest rates per 100,000 populations. In contrast, the lowest rates are in Iran (0.4), Malaysia (0.5), and Saint Lucia (0.7) [7]. Near to 50-75% of drowning happened in open water like oceans, lakes, rivers, and ponds [9] and about 60% of drowning deaths among children happen in swimming pools [9].

When a person is sinking, the lifeguards must reach him/her before 102 seconds [10]. There is a gap between victim survival time and lifeguard rescue time especially in the open waters because under the best conditions lifeguards can reach a victim in 93 seconds, however some victims can survive for less than 60 seconds [10]. This gap between the survival time and rescue time causes death. In order to increase victim survival time during the rescue process, some rescue systems were designed. These devices enabled victims to survive long enough for lifeguard rescue. Sometimes lifeguards cannot identify the drowning person due to lack of attention or high populations in the swimming pools, to solve this problem some alarm and rescue

devices were designed that are useful in swimming pools. There is a limited amount of experimental research regarding the type of water rescue equipment when helping a victim in an aquatic environment [11]. The purpose of this review was to conduct a systematic search on the existing aquatic rescue technologies.

## Material and Methods

Reviewers searched the Science Direct, Google Scholar, PubMed, Elsevier, Springer and Google patents databases by using the following keywords: swimming, beaches, swimming pool, rip current, drowning, rescue, rescue device and life guard. This search included all the published papers until 2018. We selected 23 papers during the search period. All papers abstracts were reviewed by reviewers. Studies were excluded if full text of the paper had not published also non-English language papers.

## Results

Overall 7 related papers were selected among 23 papers that were obtained based on keywords. Reviewers divided the rescue devices into three categories according to the area that they're used: 1. Devices that are used at the beaches, 2. Devices that are used in the swimming pools. 3. Devices that are used both on beaches and in swimming pools.

### Beach devices

#### Life-ring drone delivery system

One of the devices in the beach rescue process is life-ring drone delivery system. Floating device is delivering to the victim by a multi-rotor drone. Function of this system is as follows: When a person is drowning in a radio communication zone. The pilot hears call on radio and commands drone to lift off and fly to that section. On-board cameras show victim's position to the drone, then it flies to him/her and releases tether to lower the flotation device, but still hold the tether to manage its position in the water. Drone guides flotation device to victim then releases the tether after the victim grabs the flotation device. When the victim has flotation device, drone flies back to home point, therefore, the lifeguard has enough time to reach the victim[10] (Figure 1).



Figure 1. Life-ring drone delivery system

#### *The garment integrated personal flotation device*

This device is categorized in life jackets group to help navies and the person who needs assistance in water. The main aim of this jacket is to protect the airway upon entrance during the initial shock and improve

resuscitation action. A garment protects cricoid cartilage from compression that mounted dual zipper cover releases a balloon that creates a reliable mandibular shelf and bracket while simultaneously encapsulating. This device is adjustable that, a dual wall personal floatation device (PFD) with its oversized inner balloon creates extended midline crossing. A dual chambered inner balloon separates the compressed gas inflated high-pressure low-volume balloon required for a corrective turning from the higher-volume and lower-pressure orally inflated chamber which provides the additional buoyancy needed to improve floating. A dual release fabric lock handle allows for the quick release of the deflated redundant abdominal PFD which then serves as a thrown rescue inflatable device. A PFD integrated variable-displacement dual-pressure personal life raft uses compressed gas to inflate a rigid floor conferring sufficient buoyancy to support the Marines 35 lb. Rucksack[12] (Figure 2).



**Figure 2.** Garment integrated personal flotation device

### *Lifesaving wristband and gas-generator*

It is related to sea rescue and is useful for everybody (both a beginner and an experienced swimmer). The rescue wristband includes an elastic inflatable buoyant camera hat it is firmly rolled and packed into a pocket along the wristband perimeter. A gas generator device is designed for filling in the chamber. This generator produces carbonic gas by chemical reaction between 2 or more safe components. Function of gas generator device can start as result of: 1. Hand compression to special convex spot on the wristband, 2. Bending of the compact unit on the swimmer's trunks, 3. Self-start under the excessive pressure of water on definite depth when the victim lost his/her consciousness. If the chamber is filled with gas, it comes out from the pocket and forms C-shape. The size of rescue wristband can be adjusted to the swimmer's arm and compact unit that is usually is fixed to swimmer's trunk may be located on neck (back or front position) and support the head under the water as C-shape pillow [13].

### **Pool devices**

#### *Swimming pool drowning life-saving intelligent system*

The swimming pool drowning life-saving intelligent system includes a smart alarm monitor drowning that is worn on the wrist of the swimmer, an underwater sound signal receiving transformation device and a data processing device. Function of that is as follows: when a person is sinking, a sound wave signal is sent by the smart drowning monitoring alarm apparatus to the underwater sound signal receiving transformation device. The sound wave signal receives and transforms that in to an electric signal and sends this electric signal to the data processing device via a wired or wireless technology; the data processing device processes the

received signal and verifies the location of a victim then records and shows the underwater moving trajectories of the drowning person. Drowning smart alarm monitor has a pressure sensor, water depth sensors, timers and the control chip. Smart control chip drowning monitor alarm pressure values based on the position of drowning person, and the residence time of the early warning signal. If the smart alarm monitor drowning stops in a depth greater than 0.6 m adjustments of the smart drowning monitor alarm signal warning is set in advance: Underwater stop depth greater than 0.6 m more than 3 seconds, it will send a sound wave signal. As mentioned above, the smart drowning alarm monitor is provided with a manually operable button, when the button is pressed, drowning smart monitoring and alarm sends a sound wave signal for help [14].

#### *Drowning alarm apparatus in swimming pool*

This device includes a drowning detection device A that is placed on the head of a swimmer, a handhold alarm device B and the computer data processing unit C that are used by the lifeguard and the management personnel of the swimming pool, respectively. Under normal condition, the drowning detection device A sends signals to the handhold alarm device B and the computer data processing unit C at fixed time. When the head of the swimmer is under the water level, the drowning detection device A does not send any signal, a timing circuit of the drowning detection device A and the handhold alarm device B as well as the computer data processing unit C is started, if the given time reaches and the swimmer still be in the water, the drowning detection device A will flashes in order to show the position of the victim, the handhold alarm device B and the computer data processing unit C make a sound-light alarm to remind the people around the pool, the lifeguard and the management personnel of the swimming pool to execute rescue process to the victim [15].

#### **Common devices at the beach and swimming pools**

##### *Kingii wristband*

Kingii is a rescue wristband than can be used in different areas like seas and pools. This device is made of the main air cylinders, air bags and valve constituting the wand. Function of this device is as follows: in dangerous situations, the user simply moves the valve, there will be a life-saving balloon expands out and immediately filled with carbon dioxide gas. Kingii needs to bring high-pressure gas cylinders, weight up to 280g (Figure 3) [16].



**Figure 3.** Kingii Wristband

##### *Electronic aquatic survival device*

The main goal of this device is to maintain people's head above water level. The device is to be worn at the neck like a collar and can be located at both the neck and underarms. It can be activated both manually and

automatically. In a state of unconsciousness, the microprocessor is able to enable the floating tools based on water depth and time that a swimmer has been under water. The electronic device works with batteries, but it can be activated manually. Furthermore, the device is provided with biometric captors, monitoring heart beats and transmitting data to microprocessor. In case of panic, tachycardia or hypothermia, the floating tools are automatically activated. As this device can be used at the beach or in pool, it has optic and radio frequency or GPS beacons that they are useful to verify the person's location. Floating tools includes sealed bags, inflatable through bottles filled with compressed gas or liquid that has low boiling temperature. Volume of floating components is related to swimming's weight, like life jackets [17].

**Table 1.** Classification of rescue devices

Area	Rescue Device	Priority Date	Operate Procedure
	life-ring drone delivery system*	2016	
Beach	Life-saving wristband and gas generator*	2014	Manually & automatically operable device
	Garment integrated personal flotation device	2000	
Pool	Swimming pool drowning life-saving intelligent system*	2013	Manually & automatically operable device
	Drowning alarm apparatus in swimming pool*	2007	Automatically operable device
	Kingii wristband*	2015	Manually operable device
Beach & Pool	Electronic aquatic survival device	2010	Manually & automatically operable device

\*this device requires a lifeguard assistant in order to complete the rescue process.

## Discussion

According to the collected information about life-ring drone delivery system, in order to achieve the best result, it is necessary to use special systems that the cost of them is much higher than the cost of lifeguard rescue because of the high salary of licensed pilots [10]. It can be solved if lifeguards be allowed to educate at the flight school, and take a test to show their competency. An important advantage of garment integrated personal flotation device is that this kind of devices performs rescue process without presence of lifeguards but it hinders human activities, causes some inconveniences on the action and it is impossible to carry all the time wearing a life jacket [13]. Based on these reasons, it seems that it is not an efficient tool in the rescue process. About life saving wristband and gas-generator can be mentioned that due to small size of this device, it is convenient and easy to use for everyone [13]. It is generally affordable and compare to life jackets it does not hinder swimmers activities [13]. Another kind of rescue wristbands that was introduced is Kingii wristband. It provides a great degree of freedom for user like lifesaving wristband and gas-generator, but it require to bringing high-pressure gas cylinders, weight up to 280 gr. the wrist of swimmer holds much weight that is very inconvenient for the user [18]. Another difference between Kingii and life-saving wristband and gas-generator is that life-saving wristband and gas-generator has self-start option under the excessive pressure of water at definite depth, but Kingii does not have this option and is a manually operable device [18]. The swimming pool drowning life-saving intelligent system has the beneficial options like the active prevention, pre-warning and in-time detection [14]. Advantages of drowning alarm apparatus in swimming pools are providing a convenient and reliable operation alarm pool drowning [15]. It sounds that the main difference between drowning life-saving intelligent system and drowning alarm apparatus that are used in pools is in their operate procedure. Drowning life-saving intelligent system can operate automatically and manually but drowning alarm apparatus just can operate automatically [15]. Finally, electronic aquatic

survival device save people's life even when they are unable to trigger the floating tools by themselves, so it can be activated both manually and automatically by means of an electronic tool [17].

## Conclusion

Researchers report that, drowning is for the third cause of unplanned death; that swimmers, accident victims, children and recreational seeking individuals are in danger [19]. The first step in a successful rescue process is choosing the appropriate rescue device. Generally, it is better to divide this equipment regarding to the place that they are used in, need for lifeguard presence or not. According to this, these devices were divided into three categories as follow: 1. Devices that are used at beaches, 2. Devices that are used in swimming pools, 3. Devices that are used in both of them. Therefore, it is suggested that governments, owners of swimming pools, lifeguards and swimmers select the suitable devices based on items that were mentioned above. Those pursuing to invent a new device to save lives are suggested, pay attention to tracking, movement limitation, victim survival time and lifeguard rescue time. Since time is a very important factor in the implementation of water rescue operations, it will be more efficient if researchers categorize these devices based on time that is needed to perform a successful rescue process by every device.

## References

1. Kokolakis, T., A.S. Pappous, and S. Meadows, *The impact of the free swimming Programme in a local Community in the South East of England: giving with one hand, taking away with the other*. International journal of environmental research and public health, 2015; **12**(4): 4461-4480.
2. Petrescu, S., G. Pițigoi, and M. Păunescu, *The Effects of Practicing Swimming on the Psychological Tone in Adulthood*. Procedia-Social and Behavioral Sciences, 2014; **159**: 74-77.
3. Nagle, J., *What Happens to Your Body when You Swim*. 2009: The Rosen Publishing Group.
4. Saxena, A. and L. Ang, *Epilepsy and bathtub drowning. Important neuropathological observations*. The American journal of forensic medicine and pathology, 1993; **14**(2): 125-129.
5. Feldman, K.W., C. Monastersky, and G.K. Feldman, *When is childhood drowning neglect? Child abuse & neglect*, 1993; **17**(3): 329-336.
6. Brander, R.W. and J.H. MacMahan, *Future challenges for rip current research and outreach*. Rip Currents, Beach Safety, Physical Oceanography and Wave Modeling, edited by: Leatherman, S. and Fletemeyer, J., CRC Press, Boca Raton, FL, 2011: 1-29.
7. Turgut, A. and T. Turgut, *A study on rescuer drowning and multiple drowning incidents*. Journal of Safety Research, 2012; **43**(2): 129-132.
8. Szpilman, D., et al., *cuRRent concepts*. N Engl J Med, 2012; **366**: 2102-10.
9. Dietz, P.E. and S.P. Baker, *Drowning: epidemiology and prevention*. American Journal of Public Health, 1974; **64**(4): 303-312.
10. Xiang, G., et al. *Design of the life-ring drone delivery system for rip current rescue*. in *Systems and Information Engineering Design Symposium (SIEDS), 2016 IEEE*. 2016: IEEE.
11. Beale-Tawfeeq, A.K., *Triennial Scientific Review: Assisting Drowning Victims: Effective Water Rescue Equipment for Lay-responders*. International Journal of Aquatic Research and Education, 2019; **10**(4): 8.
12. Courtney, W.L. and R.M. Carmichael, *Garment integrated personal flotation device*. 2003, Google Patents.
13. Mukhortov, P.P., *Life saving wristband (variants) and gas-generator (variants)*. 2014, Google Patents.
14. L., X., *Swimming pool drowning life-saving intelligent system*. 2013, Google Patents.
15. Jiejn, *Drowning alarm apparatus in swimming pool 2007*, Google Patents.
16. Zhihong, L., et al., *Water-falling self-rescue device and bracelet 2017*, Google Patents.
17. Henuset, Y.M. and S. Bouchard, *Electronic aquatic survival device*. 2010, Google Patents.
18. Zhihong, L., et al., *Water-falling self-rescue device and bracelet 2017*, Google Patents.
19. John, S.N., et al., *Design of a drowning rescue alert system*. International Journal of Mechanical Engineering and Technology (IJMET), 2019; **10**(1): 1987-1995.

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