Design and Testing of Portable Micro Airbag for Human Safety in Water

Dr. B Biju
Professor
Department of Mechanical Engineering
Mar Athanasius College of Engineering
Kerala, India 686 666

Abhishek Anirudhan
U G Scholar,
Department of Mechanical Engineering
Mar Athanasius College of Engineering
Kerala, India 686 666

Ajay Krishnan M M
U G Scholar,
Department of Mechanical Engineering
Mar Athanasius College of Engineering
Kerala, India 686 666

Akhil M D
U G Scholar,
Department of Mechanical Engineering
Mar Athanasius College of Engineering
Kerala, India 686 666

Eldo T John
U G Scholar,
Department of Mechanical Engineering
Mar Athanasius College of Engineering
Kerala, India 686 666

***Abstract*— Drowning is a major global injury problem and is the second leading cause of unintentional injury death after road traffic injuries. As a result, many invention to prevent drowning and to rescue drowning victims have been made over the years. Drowning occurs in the ocean, beaches, lake, ponds, rivers, swimming pools etc. Increased lifejacket wear is shown to be significantly correlated with lower fatality rates across all spectrum of activities. Survivability among those casualties wearing life jackets was 94%. But no one swims around with a life jacket on and that's the reason for majority of accidents. A detailed study provides clear evidence that a coordinated approach to water safety is required. Portable micro airbag is aimed at preventing one from drowning. This is a lightweight accessory and can be incorporated into wrist bands, belts and schoolbags. The airbag system basically consist of an inflation bag, CO_2 cartridge and a pull lever that will be used to release the CO_2 gas and thereby inflating the bag. Such low cost devices, affordable for deployment in low and middle income countries, should receive particular attention, as these countries endure almost 97% of global drowning deaths. The prototype of micro airbag was fabricated and tested successfully for different environmental conditions.**

Keywords*— Drowning, lifejacket, water safety, portable airbag, buoyant

I. INTRODUCTION

Drowning is the 3rd leading cause of unintentional injury death worldwide, accounting for 7% of all injury-related deaths. There are an estimated 360,000 annual drowning deaths worldwide. Global estimates may significantly underestimate the actual public health problem related to drowning. Children, males and individuals with increased access to water are most at risk of drowning.

The Global report on drowning (2016) shows that age is one of the major risk factors for drowning. This relationship is often associated with a lapse in supervision. Globally, the highest drowning rates are among children 1-4 years, followed by children 5-9 years. 'Portable micro airbag for human safety in water' is aimed at reducing the drowning accidents reported every year. This device would act as a safety gadget for everyone in water and could save them in water in case of an emergency.

The objectives of the present work include design and fabricate a safety gadget which can further be incorporated into wrist bands, bags and belts. The testing of the portable micro airbag for human safety in water is aimed at preventing one from drowning for various real life conditions.

2. LITERATURE REVIEW

Donoghue et.all[1] (1977) cited the densities of tested subjects ranged from 1.019 to 1.095 kg/L for males and 1.048 to 1.054 kg/L for females while the densities of fresh water and salt water are generally accepted as 1.000 kg/L and 1.025 kg/L respectively. Therefore, as the densities of both the human male and female are greater than that of fresh water, humans will sink when their lungs are nearly empty unless they either swim or additional positive buoyancy is used to support their bodies. They identified from their study that, for the 50th percentile male in fresh water, 14 N of positive buoyancy force is available with the lungs at full volume. However, during an exhalation of breath, the decreased lung capacity provides a negative buoyancy force of 15 N, resulting in sinking. The same male in salt water would provide 35 N of buoyancy force with a full breath and still have 3 N of positive buoyancy force with an exhaled breath.

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Behnke et.all[2] (1995) measured the submerged mass of several men with dry masses ranging from 83 kg to 92 kg and corresponding submerged masses of 5.5 kg to 4.9 kg, with the heaviest man (92 kg) having the lightest submerged mass (4.9 kg). This was due to this person having the lowest density (1.054 kg/L) which indicated that he was carrying more body fat than the other subjects.

Yun Kyung Kan et.all[3] (1989) conducted experiments which showed that the TPU coated nylon fabrics showed high abrasion resistance, excellent bending strength, large elongation break, high flexibility and high softness.

Pitmana et.all[4] (2019) reviewed that drowning and fatalities at sea are a large concern globally. In the UK, many sea rescues are performed by the Royal National Lifeboat Institution, and this study investigates 6years' worth of their rescue data to better understand causation of drowning and what makes an incident at sea high risk. A Poisson model is applied to numerous factors recorded as part of each rescue, including environmental conditions (visibility, sea state, etc.), lifejacket wear, and response times for rescue. Increased lifejacket wear is shown to be significantly correlated with lower fatality rates across all spectrum of activities. Survivability among those casualties wearing life jackets was 94%. Incident survivability is shown to decrease at different rates per activity, as time to rescue increases. This study provides clear evidence that a coordinated approach to sea safety is required, and suggests that increased lifejacket wear among coastal and marine users would have a dramatic effect on reducing the number of drowning related deaths each year.

Davis et.all[5] (1998) An inflatable life Vest is provided including a vest and an inflatable bladder situated therein. Next provided is an air actuation mechanism comprising a mounting assembly which includes a threaded opening in communication with the inflatable bladder. In use, the threaded opening is equipped for releasable receiving a cylindrical pressurized air canister. A valve is slid ably situated above the threaded opening with a pin coupled to a bottom Surface thereof. A Spring is situated between the valve and the threaded open ing. The valve has a first unbiased orientation wherein the pin sits distant the threaded opening and a Second biased orientation wherein the pin resides within the threaded opening for effecting the release of air from the pressurized air canister. The mounting assembly further includes a lever pivotally attached to the mounting assembly and adapted to transfer the valve to the Second biased orientation upon the pivoting thereof..

Luckin et.all[6] (2014) explained that a conscious person in the water supported by a lifejacket will clear their own airway since protective reflexes are maintained. Water entering the mouth will be spat out or swallowed while that entering the trachea will cause coughing and maybe spasms of the vocal cords. Although a lifejacket prolongs the time one can stay alive, how long depends on factors including the sea state, wind, air and water temperatures, presence or absence of injuries, and the person's condition on entering the water.

Kuska et.all[7] (2016) reported that air bags are one of the most important safety innovations of recent decades, providing crucial protection for people during a crash. From 1987, when air bags were first installed in vehicles, through 2013,a total 39,886 lives were saved by frontal air bags. Frontal air bags were designed to protect both restrained and unrestrained vehicle occupants.

3. STUDY ON IMPORTANCE OF LIFEJACKET WEAR

The wear of lifejackets was seen to have the highest magnitude impact on survivability in life at risk incidents. Therefore, more investigation into lifejacket wear was undertaken. Plotting the percentage of survivors wearing lifejackets against the time to rescue shows the impact that a lifejacket has on survivability over time. There is an increase in percentage of survivors rescued wearing lifejackets from 35% rescued after 10 min, compared to 55% at 60 min. This figure provides a basic predictive capacity for survivability, for example, if 10 people were to get into a life at risk situation at sea, on average only two of the individuals would have the ability to survive without the aid of a lifejacket. Therefore, if a rescue asset will take two hours to reach or find a casualty; in order to survive two hours in the water, 80% of people would require the assistance of a lifejacket.

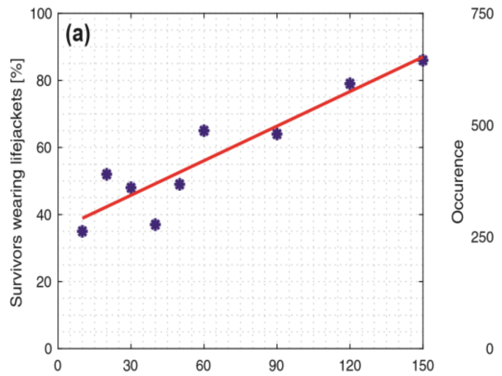

Fig 1 Casualty rate (cited from Sebastian John Pitmana,Michael Wrightd, Russell Hocken, 2019)

(a) the percentage of survivors found wearing lifejackets over time to casualty, showing that a greater number of people need to wear lifejackets in order to survive longer during life at risk incidents;

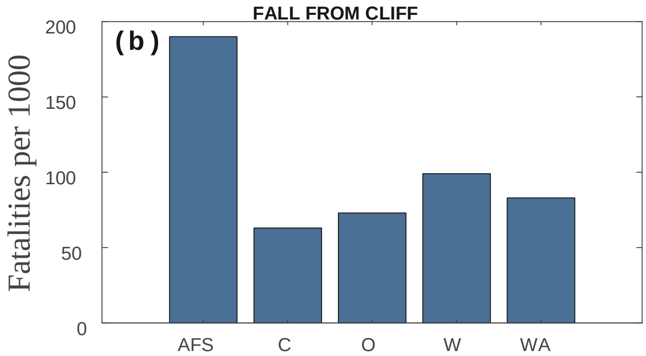

Fig 2 Fatality rate (cited from Sebastian John Pitmana,Michael Wrightd, Russell Hocken, 2019)

(b) Casualty activity is also recorded, including Angling from Shore (AFS), Climbing (C), Other (O), Walking (W), or Waterside Activity (WA).)

The increased survivability associated with lifejacket wear is clearly demonstrable, and the finding should be used to underpin drives to make the wear of lifejackets compulsory for activities at sea. Ultimately, the best approach is to ensure all water-users are prepared for any eventuality, which

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involves not just the availability of appropriate emergency equipment, but also the mandated wear and use of such equipment.

4. METHODOLOGY

4.1 Introduction

1. Incorporating airbags into wrist bands, bags and belts.
2. Consist of inflation bag, CO_2 cartridges and a pull lever to release the gas and inflating the bag.
3. Manual and software drawings are made.
4. Mathematical calculations, analysis and experiments are undertaken to determine the exact volume of gas, buoyancy etc.

4.2 Components

The main components of Portable micro air bag system are

(i) CO_2 Cartridge
(ii) Inflation bag (TPU coated nylon)
(iii) Lever mechanism

(i) CO_2 Cartridge: CO_2 cartridge Small metal container of compressed CO_2. CO_2 inflator: Tool that accepts the CO_2 cartridge, attaches to the tube valve and inflates the tyre. CO_2 cartridge will either screw into the CO_2 inflator or press into them to release CO_2.

Weight: Full cartridge: 58g, CO_2: 16 g

Inflating efficiency: A 16g cartridge of CO2 can inflate tyres to the following pressures: 700x23C: 9 bar/130 PS

Recommendations for use:

(a). Screw the cartridge into the nozzle to pierce the cartridge so it's ready to use.

(b). Hold the cartridge by the plastic cover to protect your hands from the cartridge cooling down while inflating

(c). Place the nozzle straight over the valve and push firmly to insert the valve into the nozzle in order to release the air.

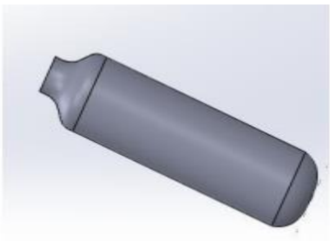

Figure 3 Software drawing of CO_2 cartridge

(ii) Inflation bag (TPU coated nylon)

Made of nylon and double sided coated, so it is waterproof. PU Coating has fabric stretch less. Even after intense uses, the fabric will retain its shape. Feel soft and the square structure is very visible (4mm x 4mm).

(iii) Lever mechanism

The CO_2 cartridge is safely fitted into a CO_2 inflator head pump valve that is provided with a lever. At the time of emergency, the user has to turn the lever that will open the cartridge and allows the CO_2 gas into the airbag thereby inflating the same.

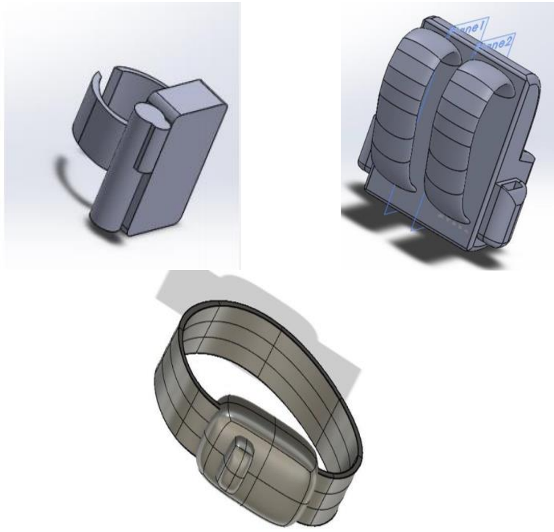

Figure 4 Software drawing of airbag incorporated into wrist bands, bags and belts

5. DESIGN CALCULATIONS FOR ACTIVE FORCES

In order to understand and model the behavior of bodies in water, the forces acting on them must be correctly applied. The form include:

(i) buoyancy (ii) drag (iii) gravity (iv) surface tension (v) wind loading

The first three of these forces are believed to be the most significant ones for the analysis of lifejacket self-righting performance.

5.1 BUOYANCY FORCE

The law that determines the static behavior of a body immersed or partly immersed in a liquid is known as Archimedes' Principle. It states that a body immersed in a liquid is countered by an upward force that equals the amount of displaced liquid. Therefore, the buoyancy force = the density of the displaced fluid x the volume of the displaced fluid x gravity.

When the buoyancy force is equal to the weight force due to gravity, an object will float on the surface of water in equilibrium because as, in this state, there is no apparent weight, the object is buoyant. The remaining amount of the object not submerged has the potential to offer additional buoyancy and is considered reserve buoyancy. However, when an object has more weight force due to gravity than the buoyancy provided by the displaced water, there is an apparent weight, i.e., the object sinks. Overall, it is the density of an object and the fluid in which it is floating that determines its submerged weight. An object's density can be calculated by the following two methods.

Method 1. If the object's dry mass and volume are known:
Density = object mass dry / object volume (kg/L)………………………………………………………… (5.1)

Method 2. If the object's dry and submerged masses are known:
Density = object mass dry x fluid density / (Object Dry mass – Object Submerged mass) (kg/L)……………………… (5.2)

The dry weight (W_d) of the object minus its buoyancy is called its submerged weight (W_s), as represented by:

$W_s = W_d - B$ ………………………………………. (5.3)

Where, W_d = Object Mass x gravity, B = Object volume x liquid density

Using Equation 5 and making the submerged mass the subject of the equation, an obese man with a dry mass of 150 kg and corresponding density of 1.019 kg/L will have a submerged mass of only 2.8 kg. As the corresponding buoyancy required to achieve a neutral buoyancy force is 27 N, it can be reasoned that obese people can use lifejackets with the same total buoyancy as those used by persons of leaner build. At the other end of the spectrum, as a lean man with a mass of 65 kg and corresponding density of 1.095 kg/L will have an increased submerged mass of 5.5 kg, the corresponding buoyancy force required to achieve a neutral buoyancy force is 54 N. Even though, in this example, the obese man is 85 kg heavier than the lean man, it is the lean man's higher density that results in his higher submerged mass of 5.5 kg.

Considering the results obtained from human density experiments and to ensure that the mouth is just clear of the water, it was recommended to the US Coast Guard in the 1960s that a minimum buoyancy force of 54 N for males and 38 N for females should be the minimum requirement for a PFD to clear the mouth with no margin.

5.3 BUOYANCY FORCE CALCULATIONS FOR AIR BAG

A lean man with a mass of 65 kg will be having a corresponding density of 1.095 kg/L.

Using equation 5.2, the submerged mass is found out to be 5.5kg.

Therefore, the corresponding buoyancy force required to achieve a neutral buoyancy force is 54N.

The difference (between the dry and wet masses) of 59.5 kg is a function of body density and volume producing 59.5 kg of upwards body buoyancy and 59.5 kg of downward body mass respectively. Therefore, as these two sets of forces cancel each other out, of the original 65kg body mass, a lifejacket is only required to support 5.5kg (54 N).

The volume of the air bag that used is

V=l x w x h...…………………………………......……..... (5.4)

$V=25 \times 50 \times 8 \times 10^{-6} = .01m^3$

Density of water ρ_{water} =1000kg/m^3

Acceleration due to gravity g =9.81m/sec

So buoyant force is

$F_{\text{buoyancy by the device}}$ =v x d x g………………...……...… (5.5)

$F_{\text{buoyancy by the device}}$ =98.1N

The portable micro airbag device provides 10 kg (98.1 N) of buoyancy.

Table 1 Variation of submerged weight and specific weight with dry weight

Specific gravity	Dry weight (kg)	Submerged weight (kg)
1.095	65	5.5
1.066	70	4.33
1.049	75	3.50
1.040	80	3.07
1.035	85	2.87
1.028	90	2.45

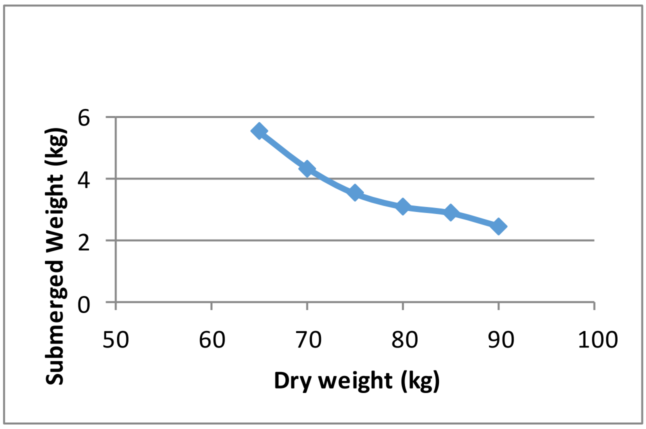

Figure 5 Variation of submerged weight with dry weight

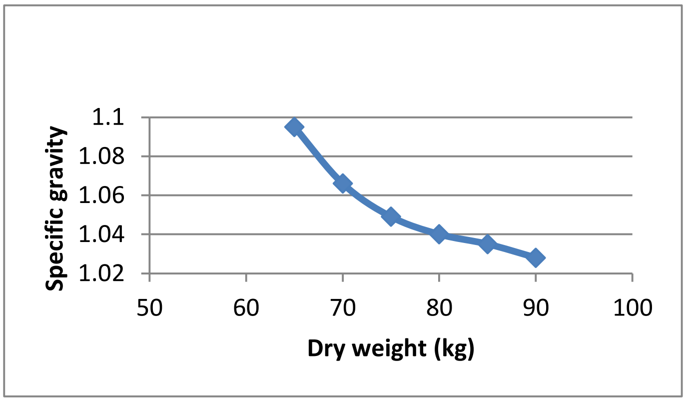

Figure 6 Variation of specific gravity with dry weight

6. SELF-RIGHTING TRIALS

A series of in-water trials were carried out at testing pool to obtain data on the self-righting characteristics of a human wearing the device. The self-righting trials were conducted and observations were made. The trials and the results are discussed in this section.

6.1 TEST FACILITY

The testing facility consists of a large water pool with necessary safety equipment for the aid of the human. Underwater video cameras were positioned in the pool so that video recordings could be made of the trials from both the side and front of the man. The person was manually positioned in the water for the tests from inside the pool.

6.2 INFLATABLE DEVICE

This is a single piece device which is put on in the uninflated state and inflated when needed by means of a gas discharge.

The buoyancy aid is provided by the airbag that is folded up and kept in the device. This is inflated by the lever that opens the cartridge which fills the airbag. The device is secured to the body with a single wrist strap.

6.3 TEST PROCEDURE

A series of trials was carried out with the device. This device was fitted to the person out of the water and tied on to the wrist as tightly as possible at the beginning of each series of trials.

The test procedure for determining righting times involves the person going underwater. It is felt that this may be a more severe test of the device's self-righting ability. The person was positioned in the initial position described above. Once the water had settled, the person was instructed to inflate the airbag using the lever. Several trials were carried out with the device and videoed for later analysis.

6.4 RESULTS

6.4.1 THE GENERAL BEHAVIOUR OF THE PERSON IN WATER

The man used in the trials is intended to represent a person feeling uncomfortable in water. When wearing the device in the water the person didn’t felt any strain around the wrist position. Moreover, it didn’t restrict his motion in water.

6.4.2 RIGHTING MODES

Throughout the trials only one mode of self-righting could be identified. In this mode, the airbag rises and the man is forced up by the force acting on the hand where the device was worn. Once the airbag is filled, the force acts on the hand and forces out of the water. The airbag is seen above the water level. It is required by the person to grab the bag using the other hand to keep the face above water. A typical response of the person in the trials was as follows:

- When released one hand (wrist level) rose up out of the water vertically.
- The other hand grabs the bag allowing righting.
- Face is kept above the water.

6.4.3 SELF RIGHTING TIME

The determination of a self-righting time is somewhat subjective since it is difficult to define precisely a starting and finishing point. This was made particularly difficult because each trial produced slightly different body motions and depth. The most workable definition of the self-righting time was found to be from the time when the hand began to rise until the time when the device was fully visible.

From this definition, typical righting times from the trials are summarized in Table 2

Table 2 Trial Self Righting Time

Device	Righting Time (sec)		
	Trial 1	Trial 2	Trial 3
Portable Micro Air Bag	5	3	2

6.4.4 DEVICE POSITION

During each of the trials, the device was seen to un-move around the hand. The strap is fitted tightly onto the hand that allows to keep it in the right position providing stability.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

The work carried out in this project has demonstrated that the Portable Micro Airbag can be used as a safety gear for humans in water.

The effect of buoyancy and gravity forces has been validated quantitatively. Good results have been also obtained in demonstration of the device.

A series of trials were carried out at the testing facility with a human to obtain data on self-righting characteristics of the device. It was found that the device is compactable and doesn’t hinder the human motions in water. Upon activating the device, it took a matter of seconds to lift the person above water.

It was also found out that the weight of the person and the depth in water is vital and influences the self-righting timing. Also, the person must be mentally conscious to activate the device upon emergency.

7.2 RECOMMENDATIONS

The current work has contributed significantly to the safety of human in water. Further benefit would be gained from additional works. In particular, further works is recommended in as follows:

- Automatic inflation technique
  The current technique requires the person to be mentally stable and conscious to activate the device upon emergency. It would be of great additional benefit and security if the device could automatically sense danger and inflate. For this the device could be fitted with pulse sensors and pressure sensors that can sense the emergency and activate the device without the confirmation.
- GPS tracker and message sending system

  GPS tracker and message sending system allows to send a panic message to a secured phone number upon activation of the device.

REFERENCES

[1] Donoghue, E and Minnigerode, S, “Human Body Buoyancy: A study of 95 Men”, Journal of Forensic Sciences, Vol. 22, No. 3, 1977, pp.

[2] Body weight divided by voloume as an index of obesity. 1942. Behnke AR Jr, Feen BG, Welham WC.

[3] Application of Electrospun Polyurethane Web to Breathable Water-proof Fabrics Yun Kyung Kang, Chung Hee Park , Jooyoun Kim , and Tae Jin Kang.

[4] An analysis of lifejacket wear, environmental factors, and casualty activity on marine accident fatality rates Sebastian John Pitmana, Michael Wrightd, Russell Hockena.

[5] Inflatable life west, Claude D. Davis, Sr.; Douglas M. Edsall, both of 315 Holly Manor Rd., Catonsville, Md. 21228, Appl. No.: 911,56, Filed: Aug. 14, 1997

[6] Luckin., Peddie, C., and Watson, J., 2010. A review of the nature of diving in the United Kingdom and of diving fatalities (1998–2009). In: Recreational Diving Fatalities Workshop Proceedings, pp 99–118.

[7] Air Bag Safety – An update, Thelma C Kuska, Palos Heights
[8] World Heath Organisation, 2005, A new definition of drowning: documentation and prevention of a global health problem, WHO, accessed 30 October 2013, http://www.who.int/bulletin/volumes/83/11/vanbeeck1105abstract/en/
[9] Wyle Labs Huntville ALA, 1978b, Personal Flotation devices research Volume 2, Research report, ADA058738, NTIS, accessed 10 March 2015, https://ntrl-ntisgov.wwwproxy0.library.unsw.edu.au/NTRL/dashboard/searchResults.xhtml
[10] Peden McGee K, Sharma G.The injury chart book: a graphical overview of the global burden of injuries . Geneva, Switzerland : World Health Organization, 2002.
[11] Vyrostek SB,Annest JL ,Ryan GW .Offi ce of Statistics and Programming, National Center for Injury Prevention and Control, USA. Nonfatal and fatal drownings in recreational water settings— United States, 2001– 2002 . MMWR Morb Mortal Wkly Rep 2004 ; 53 : 447 – 452 .
[12] Geddis DC The exposure of pre-school children to water hazards and the incidence of potential drowning accidents . N Z Med J 1984 ; 97 : 223 – 226
[13] Wintemute JG . Childhood drowning and neardrowning in the United States . Am J Dis Child 1990 ; 144 : 663 – 669