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Aviation Medical Acceleration Laboratory

NADC-MA-6135 9 August 1961

Some Medical Contraindications to the Use of the Standard Life Jacket for Survival

Bureau of Medicine and Surgery
Task MR005. 13-4003. 4 Report No. 1

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Some Medical Contraindications to the Use of the Standard Life Jacket for Survival

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SUMMARY

Survival from a disaster at sea is dependent upon the reaction of the victims to four major stresses; (1) spiritual failure, (2) heat loss and thermal failure, (3) dehydration and fluid balance failure, and (4) inanition and energy failure. The Mae West type of flotation equipment causes two deleterious physiological effects: (1) profuse diuresis based upon the Gauer-Henry left atrial volume receptor reflex which is stimulated by the negative pressure breathing required in partial water immersion, and the externally applied gradient pressure, and (2) the rapid heat loss from the immersed part of the body which would be incapacitating even at sea temperatures of 78°F which are now thought to be innocuous. These physiological effects which result from the use of the Mae West type survival equipment increase the severity of an already overwhelming stress. An alternative type of individual flotation garment which would obviate many of these difficulties has therefore been recommended for further consideration.

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INTRODUCTION

For thousands of years man has been coursing over the waters of the earth in ships, ever larger and faster. He has made great technical advances in ship building and seamanship except in one area, techniques of his own survival after disaster at sea. Prior to the 19th century, life boats of questionable seaworthiness, inadequate capacity and with no provisions represented the sole means of survival. History and the literature of the sea provide vivid details of suffering to document the inadequacy of this technique alone. It was not until 1806 that Daniel of England developed a prototype of our modern life jacket. It took 48 years more before the English Parliament passed laws requiring that they be carried aboard ships and still forty more years before one life jacket was provided for each passenger by statute (1). In 1914, stimulated by the "Titanic" disaster, an international convention for safety of life at sea, appropriately called SOLAS (solace), was held in London with 14 nations represented. They agreed to require sufficient life boats and life saving appliances to accommodate all passengers. Other than nominal quantities of food and water were not a mandatory part of survival equipment until the early 1940's. In 1948 and 1960 additional SOLAS conventions were held and innovations incorporating modern electronic equipment for prevention of ship collision were agreed on but no new concepts for the protection and survival of the individual after disaster were developed (2).

Despite the many technological advances in the last two decades, marine disasters over the world have continued at the rate of one ship of over 100 gross tons sunk every other day and three to four ships severely damaged each day. In the decade of the 1950's, 6,115 lives were lost in accidents related to calamity at sea. This number approximates 600 lives lost per year and is comparable in number to the 725 lives which were lost in civil and military air transport disasters in 1959 (3).

It should further be noted that in time of war conventional life boats are not carried aboard military vessels at a time when the probability of a maritime disaster is increased, so that the life jacket then assumes increasing importance in survival. This being the case it is surprising that no one has seriously challenged the device as a vehicle for survival nor has there been much effort directed to its improvement or to the study of the consequences of its use.

To what physiological and psychological stresses will the survivor of a disaster at sea be subjected when using a life jacket? It is possible to consider them under four general categories: (1) Spiritual failure, (2) Heat loss and thermal failure, (3) Dehydration (fluid failure), and (4) Inanition and energy failure.

SPIRITUAL FAILURE

Although it is impossible to quantitate this stress, it can hardly be dismissed lightly, and may well account for the discrepancies between experimental data and the accounts of disasters. The panic and fear of an actual emergency enhance the physiologic attrition and the seemingly endless discomfort lead soon to hopelessness which death, no longer unwelcomed, relieves too soon. Critchley summarized the psychological factors which affected survival from disasters at sea as follows (4):

> "It is clear from statements of the surviving minority that physical factors, e.g., age, sex, robustness, habitus , though important, are less significant than the more intangible psychological considerations."

These conditions which bias the result of disaster against man are lacking in most laboratory studies of human tolerance to hostile environment, i.e., isolation, cold, heat, etc. In the laboratory the subject is aware of the essentially benign nature of the experimenter and knows that the termination of the stress is always in his control. Experimental results are thus probably close to optimal and may give man a false sense of security, particularly if he indulges in the fantasies born of extrapolating his experimental curve in prolonged time. With this point in mind, the problems of immersion can be examined in more detail.

HEAT LOSS AND THERMAL FAILURE

The problem of surviving immersion in very cold water although extensively studied (5, 6, 7) is still far from conquered by existing protective equipment.

As a stress, cold may be so overwhelming as to terminate life immediately upon exposure by precipitating coronary occlusion or lethal ventricular arrhythmia. Even if these immediate cardiac effects are avoided the stress factors of cold become predominant long before the other stress effects of immersion become significant. The initial compensatory reflexes are doubtless complex but ultimately the cold problem reduces to the age old concept of supply and demand. The supply of metabolic heat available from the body's energy stores must meet the demand imposed by the cold stress or heat lost from the body to the ambient H_2O environment or else the body core temperature will fall. It will continue to fall along a decaying exponential curve until the body temperature reaches a level where the metabolic heat supply is sufficient to meet the losses and maintain the gradient in temperature between the water and the body core. The physical laws describing this situation were formulated mathematically by Isaac Newton some three centuries ago. The law states that the temperature of a heated body surrounded by a medium of constant temperature decreases at a rate proportional to the instantaneous difference in temperature between the body and the medium. The fact that the body generates heat does not change this fundamental relationship once heat production and the body defenses against heat loss, particularly vasoconstriction, reach maximum. These only limit the degree of drop in core temperature and create the necessary condition to allow a gradient to exist between the body and water with core temperature becoming constant, even if reduced from the normal range. To illustrate, let us assume a man of average size, i.e., 80 Kg, is suddenly immersed in H_2O of 10°C (50°F). The temperature gradient from core to skin surface is 28°C and with a surface area according to Dubois of 2 square meters, heat loss is of the order of 400 - 450 Kg - cal/hr. Even if we assume that the metabolic rate was increased at four times the basal rate or roughly 320 Kg - cal/hr it would mean that the body, while immersed, was cooling at the rate of 5°F (2.35°C) per hour. Even if the cardiac irregularities and hypoxia associated with vasoconstriction did not lead to death prematurely, the maximum survival that could be expected would be 2 1/2 - 3 hours because of the heat loss.

Figure 1, the first figure from Molnar's (8) collected data drawn from a large number of cases in World War II shows the relationship between the sea temperature and hours of survival. The heavy line represents the maximum expected survival possible since no cases are reported which lie to the left of the line. The sharp knee in the curve between 60 to 70°F is of particular interest since it represents a rather critical area between a cold stress which hopelessly overwhelms the body's defenses and metabolic heat capacity, and one at which indefinite survival is seemingly possible at sea temperatures above 77°F. More than a third of the earth's seas have a mean temperature in excess of this level (9), yet to our knowledge only three men are known to have survived immersion of 84 hours duration (10). They were the residue of a group of 10 or more, the rest having succumbed and even these were *in extremis*, semicomatosed with dehydration and flaccid with weakness. They represented a shabby lot to represent humanity as record holders for duration of immersion survived. On land, even in desert country, survival without food and water for 84 hours would be expected and without the extraordinary physiologic decrement demonstrated by these men.

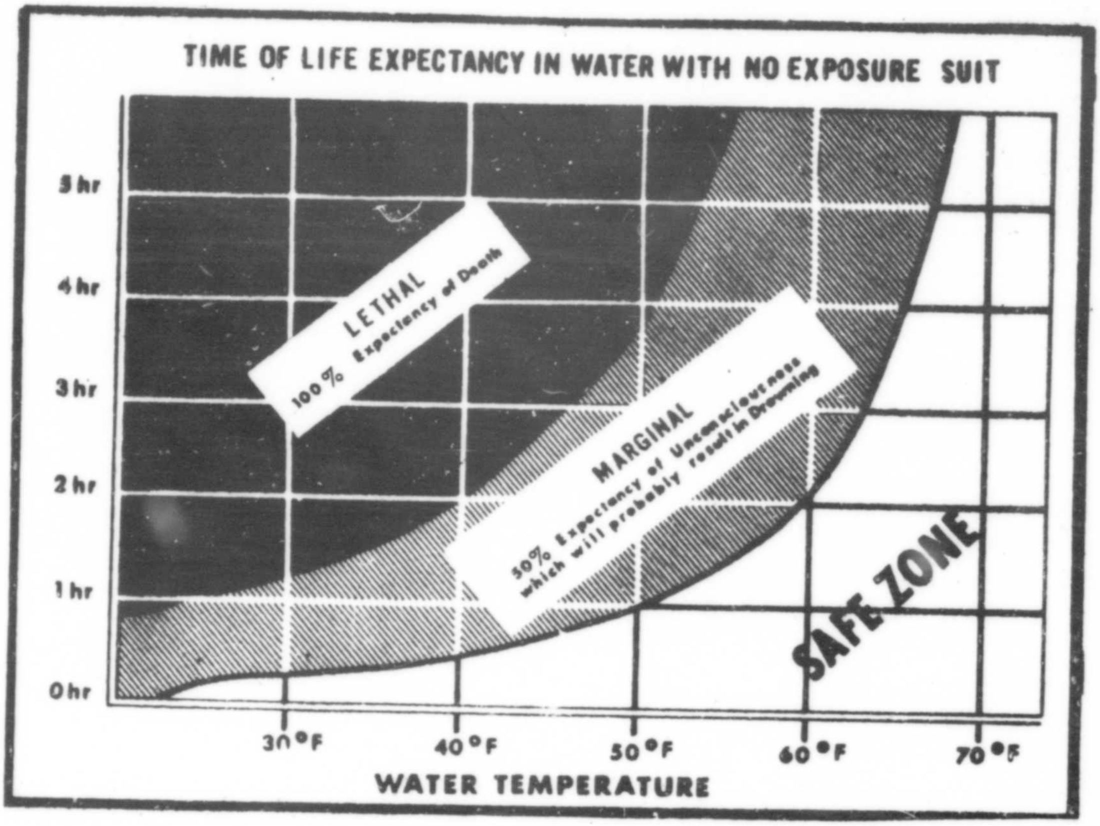


Figure 1. Graph of time of life expectancy in water with no exposure suit. Chart used by U.S. Navy.

If indeed it is from the sea that we have come, it is not to the sea that our subsequent evolution has prepared us to return. The preservation of body temperature when immersed even in the warmest ocean requires energy which at a very minimum must maintain a gradient of 7°C (12.6°F) which would still require an energy expenditure of 3000 Kg-cal/day. Thus the mildest anticipated cold stress imposes daily energy requirements comparable to eight hours of swimming or carpentry, or approximately four times the basal metabolic requirement. If the survivor were asleep at the minimal energy level imposed by his environment his energy expenditures would, by comparison, make those of the worst cases of Graves disease pale to insignificance. Since the survivor is fasting, this energy must come from his stored supplies or the breakdown of his body tissues, which doubtless accounts for the remarkable ennervation characteristic of survivors of prolonged immersion. In our studies (11) of 18 to 24 hours duration with the thermal gradient purposely minimized, this weakness and asthenia has been a striking feature, although perhaps due to a further factor which will be developed later. The body, like any good computer with an overriding instruction to preserve itself, has set its physiologic parameters at maximum to minimize the consequences of cold stress. By monitoring the sensory inputs continually, it computes the optimal relationship of the many complex variables involved to minimize the loss of heat from the body without jeopardizing its safety. The gradient between the body core and its skin is an important factor in the metabolic costs. The core temperature can drop several degrees without sequellae other than shivering which begins when core temperature drops about 0.6 -1°. The physical work of shivering is an important source of additional calories and some people believe that it is the only source of increasing heat production. Shivering gradually subsides, however, and with it heat production at core temperatures below 95° and by the time it reaches 88° the metabolic heat has reached basal levels. Unconsciousness has usually occurred before this level is attained and the rate of heat loss rises with death following in seeming comfort.

The protective insulating effect of heavy clothing has been demonstrated frequently, both experimentally and in the records of actual disasters. The particular temperature range in which added insulation makes the most significant contribution is 60 to 70°F where a small reduction in heat loss will prolong life three-to four-fold. The prolongation of life allows other stresses to develop increasing significance as the limiting factors in survival. Since the mean temperature of over one half of the area of the seas are above 68°F (9) the problems of prolonged immersion given the moderate protection of insulating clothing are very large.

INANITION AND ENERGY FAILURE

Inanition and energy failure become significant factors in limiting life only after prolonged immersion. Survivors in life boats have not reported hunger as a prominent symptom in any but the very longest ordeals (12). The great suffering from thirst has rendered even the food which was available, pemican, etc. unattractive and there is reason to believe that much of the concentrated food in survival kits would serve primarily to add to thirst while supplying only 4-800 cal (13). The absorption of concentrated food from the intestinal tract requires the secretion of a volume of fluid from the plasma sufficient to render the intestinal content isotonic with the plasma. In conditions on which the plasma volume is critically reduced, further loss may lead to symptoms akin to those of the dumping syndrome which override the feelings of hunger. In experimental animals a close correlation is seen between body fluid osmolarity and spontaneous food intake (14) and it is further demonstrated that peristalsis and gastric "hunger" (15) contractions are decreased or eliminated by cold. These factors explain in part the relative mildness and infrequency of the complaint of hunger. In immersed subjects abdominal discomfort is almost universally present after three hours. Subjectively, in our experimentation the discomfort is identical to hunger contractions, differing only by disappearing almost at once on leaving the water. This distress though impossible to differentiate subjectively from hunger is clearly related to the hydrostatic gradient of pressure along the axis of the abdomen, which forces the intestinal gas to the upper abdominal portions' of the GI tract, stomach, hepatic and splenic flexures and the transverse colon. Here it is trapped by the externally applied gradient of pressure and increasingly distends the bowel. The bowel responds to the abnormal distention by strong peristalic contractions and discomfort. Removal of the gradient pressure relieves the distention and the distress, as will eructation of air or passage of flatus. Pitressin, though administered to evaluate urinary flow, was notable through its useful effect on gastrointestinal tonus in releasing the compressed gas from the nearest available portal. Thus what appeared to us as severe hunger was found to be due to other physical factors and so it may have been with others under actual survival conditions.

DEHYDRATION - FLUID FAILURE

Although the human body is around 70% water, the available water stores are greatly limited. Compared to the readily secretable water the daily inexorable losses amounting to 3% of the body water are such that man is nearly as dependent on H_2O as are fish. Under optimal conditions life is possible for only 10 days without fluid replacement and effective purposeful living continues for perhaps half this time. In air, man is a veritable evaporative wick losing into the atmosphere a minimum of perhaps a liter of water from the lungs and skin and a half liter of urine. Therefore we see a daily loss of 3% of body fluid per day, when the deficit reaches 22% death is near. Thirst commences early and is severe after 3% of body fluid is depleted.. By the time water deficiency reaches 8% there is marked thirst, dry tongue and mouth, oliguria and weakness. A further loss of 2-3% leads to prostration and impaired consciousness (16). As the extracellular fluid becomes hypertonic, it draws fluid from the cells according to Donan equilibrium and thus minimizes the osmotic change in the extracellular phase. As a consequence the primary fluid loss is cellular which contributes about three quarters of the total H_2O loss. Obviously this distribution will prevent vascular collapse and death which would occur after two days if the drain were from the plasma volume alone.

The situation of water deprivation while immersed would at first hand seem to be minimized. Evaporation from the skin is absent, the air over water is close to saturation, tending to minimize losses from the lung. There may even be a significant diffusion of fluid from the sea into the skin as shown by Buettner (17), although to be sure the salinity of sea water would only aggravate the solute load on the kidney and hypertonicity of the plasma. All considerations taken into account, immersion would seem to minimize fluid loss if it were not for one additional complication of this status, a striking water diuresis.

The effect, though not fully appreciated on its implications, was noted by Henry Hartshorne (18), a Philadelphia physician writing in 1847. In taking exception to a statement of a colleague practicing hydrotherapy he said:

> "If this blood be thus driven by the bath from both the external and internal ports, what becomes of blood? The heart and great vessels, it would seem, must at least be burdened. Such is to a degree the case; and it is perhaps the stimulus of this fullness and distention or its action on the elasticity of those vessels and the heart that constitutes the reaction which leads forth the urine in abundant effusion. Such overloading of the heart and great vessels by the ingathering of the contents of all the great organs would be dangerous in every case if the volume of the blood remained the same."

Little additional knowledge has been added since this original description although a few details as to the location of the trigger and mediating nerves of this reflex have been noted. Bazett (19) in 1924 described a diuresis associated with warm baths but felt it was related to changes in renal hemodynamics. In 1938 Behnke (20) noted and studied the excessive urination in "hard hat" divers during deep experimental tank dives but the SQUALUS disaster aborted his investigations. Gauer (21) in 1954 further elucidated the nature of the problem by noting that it was a function of negative pressure breathing.

In 1956 Henry et al (22) described experiments which seemed to localize the trigger for the diuresis as a left atrial stretch receptor activated by diastolic filling level and mediated through the vagus. The increased vagal discharges, by routes not yet delineated, inhibit the secretion of antiduretic hormone with resulting diuresis. We have demonstrated, as have others, that the diuresis is blocked by subcutaneous pitressin. Further, there is a delay of 20 to 30 minutes after commencing negative pressure breathing or immersion before the diuresis begins. This would be the time required for antidiuretic hormone present in the blood to be excreted. In immersion, in addition to the negative pressure gradient of inspired air which increases the thoracic blood volume the factor of pressure applied to the skin compressing the superficial blood vessels forces blood centrally. In water below 86°F which includes almost all sea water, active vasoconstriction leads to still greater increase in central blood volume. With each additional factor tending to reduce peripheral blood volume while distending the central vessels, an increased increment in urine output might be expected. Figure 2 shows the effect of these factors on a given subject as being representative of our experience. The subject is immersed to the neck in a Mae West life jacket. On the abscissa the cumulative urine output is recorded against time in hours on the ordinate. The steepest rate of urine output is the line on the left and was obtained with the subject in water at 77°F and without fluid replacement. With the subject in water at 95.2°F the more moderate diuresis is seen with the plot of its time course on the right. The difference in these studies we explain on the basis of the increased vasoconstriction in the cold water. The study should have been prolonged to demonstrate the tendency more clearly but humanitarian considerations and a drop in oral temperature of two degrees mitigated against it. This is the temperature which Figure 1 earlier indicated as being tolerated indefinitely. In the plot midway between these studies we see the nearly linear urine output with time representing effect of replacement orally by water of the volume of urine secreted in the preceding hour. The ambient water temperature was

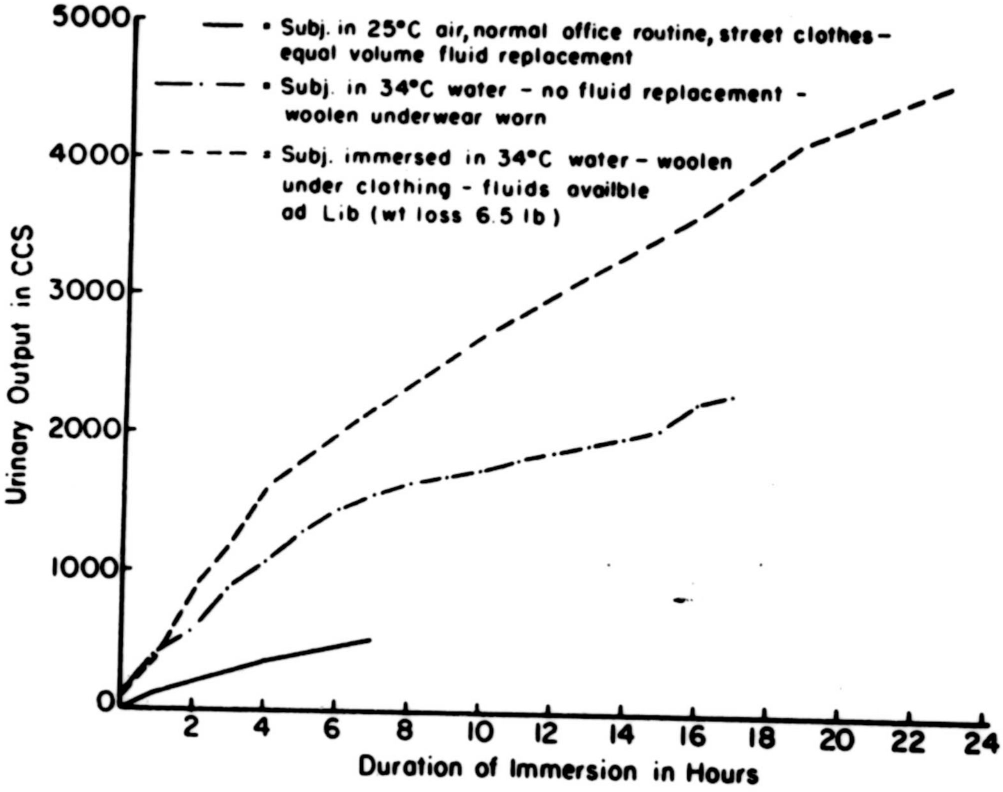
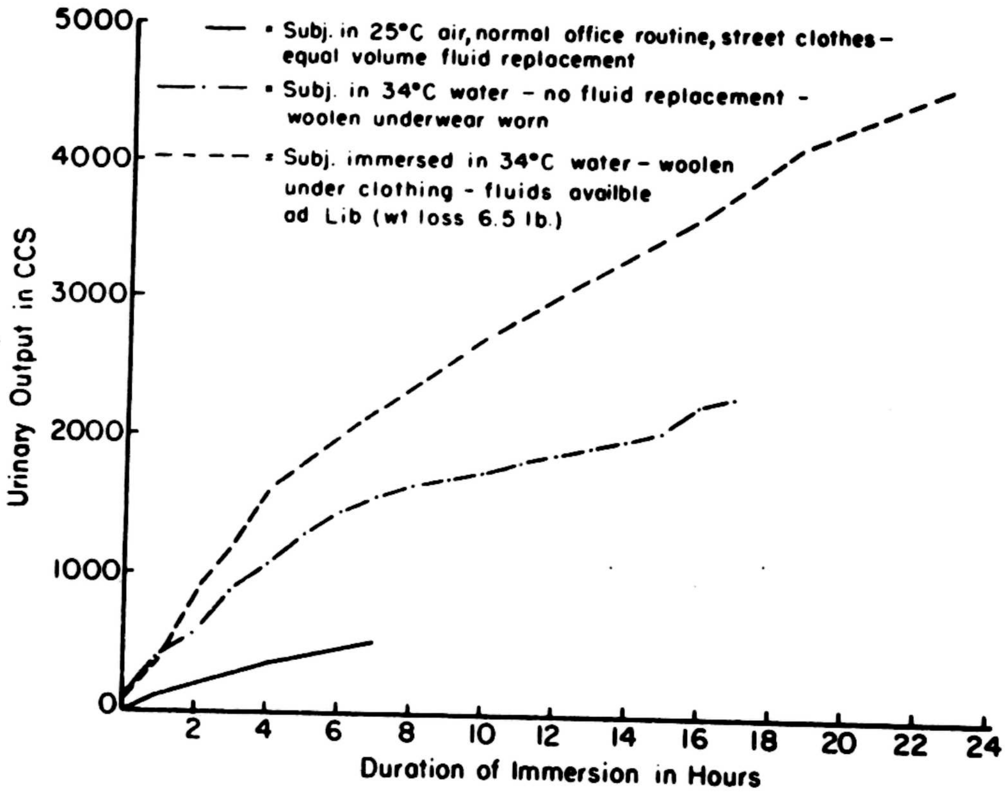


Figure 2. Graph showing relative rates of urinary excretion during water immersion.

95°F. In spite of the replacement the rate of urine output did not exceed that of the study without replacement at so-called optimal sea temperatures.

Figure 3 shows the magnitude of this diuresis. As previously, the cumulative output is plotted against time. The bottom line shows the urine output during a normal 8-hour working day in a comfortable air conditioned office. The urine volume was replaced by fluids. The middle line shows an 18-hour study without replacement and the upper line with replacement both at water temperatures of 95°F.

These results are typical responses which we have seen in all our subjects. The mean values of urinary excretion during our experiments are shown in Table I. They clearly demonstrate that immersion, far from protecting against water loss, aggravates it. The rapidity of the water loss leads to a demonstrable hemoconcentration in 8 hours as shown by a rise in hematocrit of 3 to 4%. It must be emphasized that the studies were conducted at water temperature of 95° to minimize the effects of heat production which would impose additional solute load on the kidney. When replacement is not available a 3% drop in body weight is commonly achieved in 10 hours of immersion and even with replacement on an ad libitum basis a similar drop is seen in 24 hours. These losses are associated with symptoms of rather marked fatigue and weakness circumoral pallor and in several subjects paroxysmal atrial tachycardia. The origin of this striking fatigue is not clearly elucidated but it is far more severe than is seen with comparable dehydration in the air. It may be related to salt loss which we have shown in our subjects to be greater than expected in an ordinary 24-hour urine volume. Unlike negative pressure breathing per se, it also seems immersion leads to a great reduction in effective circulating blood volume due to the pressure of water on the body which reduces the blood in the peripheral vascular compartment to a minimum. When the pressure is removed from the peripheral tissues the reduced volume is unable to fill the available volume adequately and a condition resembling impending shock from acute blood loss results. This physiological alteration demands immediate replacement of the blood volume by plasma, as the primary therapy for survival of prolonged immersion. The factor of depletion of glycogen stores must not be overlooked. Oxygen uptake measurements in subjects immersed in water at 95°F have shown the O_2 uptake to be two to three times their calculated basal level. Others (23) have reported the work of breathing in negative pressure breathing to be increased perhaps twofold; the cardiac output and stroke volume are elevated half again their normal values. Thus even without the problem of heat loss to increase the metabolic demand there is reason to believe that immersion



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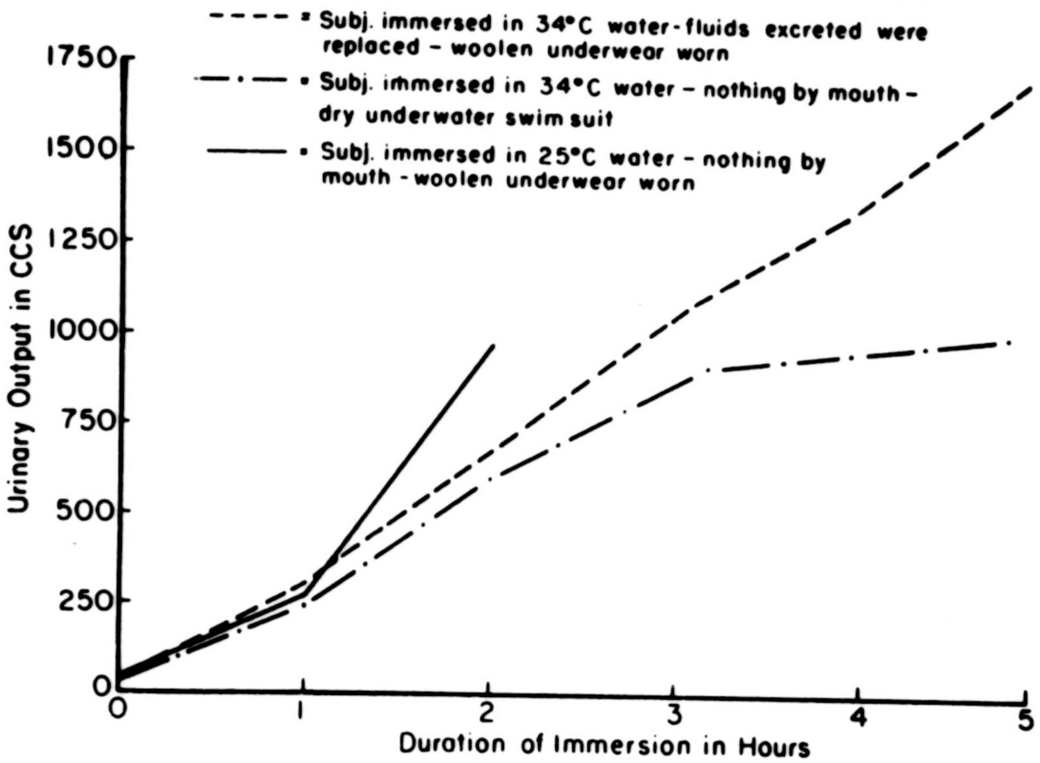

Figure 3. Graph showing effects of prolonged immersion with and without fluid replacement compared to output in air during normal work day.

TABLE I

AVERAGE RATES OF URINE EXCRETION UNDER THE VARIOUS EXPERIMENTAL CONDITIONS EVALUATED

Conditions of Experiment (1) H_2O temp. (2) Fluid Replacemt.	Average rate per hour of urine excretion				
	Total experiment cc/hr	Maximum for 1 hr	0-4 hr	4-8 hr	8-end
Normal 8 hr working day 25°C ± .5° With Replacemt.	68	82.5	68	68	--
With Replacemt. 34.5 ± .5°C	306.7	639	409	169	--
Pitressin (10 pressor units) With Replacemt. 34.5° ± .5°C	248.8	408.2	284.8	188.5	--
No Replacemt. 34.5° ± .5°C	225.2	465.1	278.3	154.8	76
Cold No Replacemt. 25°C	465	650	465	--	--

for the reasons above would rapidly lead to depletion of stored glycogen and enervation, with the cold to contend with the depletion becomes fulminating. Certainly those of us who have experienced the effects of even 18 hours of immersion, would rise, if we could, in salute to the heroic stamina of those hardy souls who survived immersion for 84 hours.

SUMMARY AND RECOMMENDATIONS

As a consequence of these preliminary studies into the physiological effects of water immersion up to neck level and the deplorable record of survival at sea, it must be concluded that the standard Mae West life jacket leaves much to be wanted as a vehicle for survival. The severe attrition of cold, of diuresis, of increased cardiorespiratory work, of the other unphysiologic consequences of hanging by your armpits in a field of gradient pressure like bait for attack by denisons of the deep, if not caused by, are surely not solved by the use of such a device. The convenience of its packaging, its price, the ease of getting into it are hardly sufficient if something better is available. Our solution is tentatively proposed and is shown in Figure 4. It is a complete inflated suit presently used by British Royal Navy submariners for escaping from disabled submerged submarines. It is light - present model weighs 7 1/4 pounds. With less rugged construction, it might weigh 5 pounds One model is made with a zippered ventral entrance (Seis Mk-5) so that it can be entered quickly, the insulating properties are excellent, it is inflated by a CO_2 capsule but can be inflated by mouth. Diuresis is minimized by floating (Figure 5). We have found it to be very comfortable and, even when fully inflated, mobility is not inconvenienced seriously.

The authors recommend that further consideration be given to this concept which, in its present form, overcomes many of the objectionable features of the standard life jacket. Further studies will suggest methods of perfecting the device for the specific requirements of survival at sea.

Figure 4. Subject wearing British Royal Navy Submarine Escape and Immersion Suit.

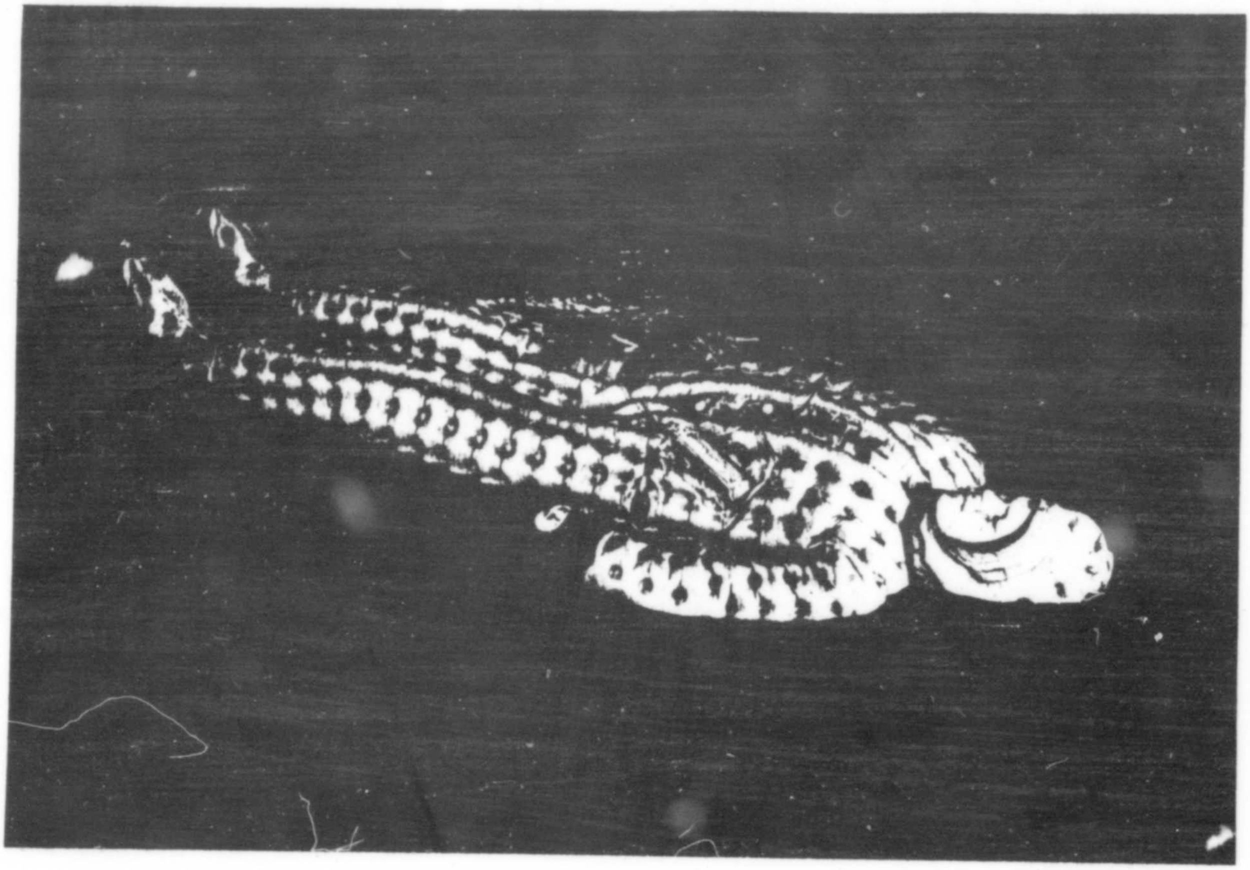

Figure 5. Subject afloat while wearing British escape suit.

REFERENCES

1. Critchley, MacD. Shipwreck - Survivors, A Medical Study, J. & A. Churchill Ltd., London, 1943, p. 90.

2. Vaughn, C.H. International Standards for Safety at Sea. The 1960 Solas Conference. J.A.G. Journal, May 1960, p. 3.

3. World Almanac and Book of Facts for 1960. New York World Telegram and Sun, New York, N.Y.

4. Critchley, MacD. Shipwreck - Survivors, A Medical Study, J. & A. Churchill Ltd., London, 1943, p. 75.

5. The Treatment of Shock from Prolonged Exposure to Cold: Especially in Water. (Dachau Concentration Camp Experiments) Leo Alexander, War Dept., Combined Intelligence Objectives Subcommittee, 10 July 1945.

6. Behnke, A.R. CAPT, MC, USN and C.P. Yaglou, LCDR, S, USNR. Responses of Human Subjects to Immersion in Ice Water and to Slow and Fast Rewarming. Naval Medical Research Institute, Bethesda, Md. Tech. Rpt. #11, 23 March 1950.

7. Spealman, C.R. Body Cooling of Men and Animals Immersed in Water. Naval Medical Research Institute, Bethesda, Md. Tech. Rpt. #5, Project X-189, 5 Feb 1945.

8. Molnar, G.W. Survival of Hypothermia by Men Immersed in the Ocean. JAMA 13: 1046-1050, 1946.

9. Sverdrup, H.U., M.W. Johnson, and R. H. Fleming. The Oceans - Their Physics, Chemistry and General Biology, In Surface Temperature of the Ocean Charts. Prentice - Hall Inc., New York, 1942.

10. Critchley, MacD. Shipwreck - Survivors, A Medical Study, J. & A. Churchill Ltd., London, 1943, p. 4.

11. Beckman, Edw. L. CAPT, MC, USN, and R.E. DeForest, LCDR, MC, USN, et al. Some Physiological Changes Observed in Human Subjects During Zero G Simulation by Immersion in Water up to Neck Level. U.S. Naval Air Development Center, Aviation Medical Acceleration Laboratory, Johnsville, Pa. Report NADC-MA-6107, 10 April 1961.

REFERENCES cont.

12. Critchley, MacD. Shipwreck - Survivors, A Medical Study, J. & A. Churchill Ltd., London, 1943, p. 7.

13. Critchley, MacD. Shipwreck - Survivors, A Medical Study, J. & A. Churchill Ltd., London, 1943, p. 99.

14. Cizik, L. J.: Long-term Observations on Relationship between Food and Water Ingestion in the Dog. *Am. J. Physiol. 197*: 342, 1959.

15. Mayer, J. and Sudsaneth, S.: Mechanism of Hypothalmic Control of Gastric Contractions in the Rat. *Am. J. Physiol. 197*: 274, 1959.

16. Weisberg, Harry F.: Water, Electrolyte, and Acid Base Balance. Williams & Wilkins Co., Baltimore 1953, Chap. 7 - Dehydration, p. 86-95.

17. Buettner, Konrad J. K.: Diffusion of Liquid Water through Human Skin *J. Appl. Physiol. 14*: 261, 1959.

18. Hartshorne, H.: Water Versus Hydropathy or An Essay on Water and the True Relationship to Medicine. Philadelphia, 1847.

19. Bazett, H. C., Thurlow, S., Crowell, C., and Stewart, W.: Studies on the Effects of Baths on Man. II. The Diuresis Caused by Warm Baths, Together with Some Observations on Urinary Tides. *Am. J. Physiol. 70*: 430, 1924.

20. Behnke, A.R., CAPT, MC, USN(Ret): Personal Communication.

21. Gauer, Otto A., Henry, James F., Sieker, Herbert, O. and Wendt, Wallace E.: Effect of Negative Pressure Breathing on Urine Flow. *J.C.I. 33*: 287, 1954.

22. Henry, J.P., Gauer, O.H. and Reeves, J.L.: Evidence of the Atrial Location of Receptors Influencing Urine Flow. *Arc. Res. 4*: 85, 1956.

23. Bader, M. and Bader, R.: Negative Pressure Breathing. *Am. J. Med. 28*: 333, 1960.

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