Health & Fitness Journal

of Canada

Copyright © 2015 The Authors. Journal Compilation Copyright © 2015 Health & Fitness Society of BC

Volume 8 January 30, 2015 Number 1

ARTICLE

A polar bear swim, anyone? Risks and counter-measures.

Roy J. Shephard[1]

Abstract

Objective: Polar bear swims and other activities involving immersion in frigid water are becoming ever-more popular. This brief article traces the origins of such events, assesses the associated risks to health, and suggests appropriate countermeasures. *Methods:* Historical information on polar bear swims, Epiphanal "blessing of the waters" and ultra-long distance swimming events was sought on the Internet. Data on associated gasp reflexes, ventricular fibrillation, pulmonary oedema, hypothermia and other hazards, together with appropriate counter-measures was found by standard Ovid/Health Star and Pub-Med searches. *Results:* There are few formal statistics on the morbidity and mortality associated with participation in cold-water events. Early drowning from poorly coordinated breathing seems a real possibility, and in older individuals cardiac arrhythmias may progress to ventricular fibrillation or asystole as the body cools. However, a dangerous degree of hypothermia is unlikely with immersion of less than 30 minutes. The risks of drowning and cardiac arrhythmias are best countered by undertaking cold water immersion in the presence of someone who is familiar with resuscitative techniques. Hypothermia can be avoided by not remaining in the water longer than 5 minutes; in ultra-ling distance swimming, those with substantial body cooling should be referred to a hospital familiar with the treatment of hypothermia. *Conclusions:* The risks of a polar bear swim for a healthy young adult seem minimal, provided that the activity is not performed alone, that immersion is not unduly prolonged, and alcohol ingestion is avoided. However, the immediate shock of immersion may provoke cardiac arrhythmias in vulnerable older individuals. Ultra-long distance swims carry greater risks, and the condition of those involved must be monitored regularly by the crew of pilot vessels. **Health & Fitness Journal of Canada 2015;8(1):14-21.**

Keywords: Cardiac arrhythmias; Gasp reflex, Hypothermia; Ventricular fibrillation

From [1]Faculty of Kinesiology & Physical Education, University of Toronto, Toronto, ON.
E-mail: royjshep@shaw.ca

Introduction

Perhaps in part as a reaction to the dullness and safety of modern urban life, young adults have shown a growing trend to participate in a variety of physically stimulating adventure sports, many with a high risk of injury (Burr et al., 2013). Among these burgeoning forms of activity, several involve exposure to frigid water (polar bear swims, "blessing of the waters," and ultra-long distance swims across Lake Ontario and the English Channel). This narrative review looks briefly at the history of such events, the associated health risks, and appropriate counter-measures.

History of cold-water events

Polar bear swims. As might be anticipated, the New Year's Day tradition of a polar bear swim had its origin in Canada. In Vancouver's English Bay, a small group of between five and 10 enthusiasts began this tradition in 1920 under the leadership of Peter Pantages, a swimming enthusiast and a nephew of the theatrical impresario, Alexander Pantages. By 1976, the English Bay event attracted 641 active participants and several thousand spectators. In 1985, when the water temperature was only 3°C, 1718 hardy swimmers ventured into the Georgia Strait, and in 2014 (when the water was a balmy 8°C), numbers had risen yet further, to 2550 participants.

Spectators contributed substantial donations to the Vancouver Food Bank.

Similar polar bear events are now held at 15 or more locations across Canada, notably White Rock, BC, Toronto, ON, and Oakville, ON. The White Rock event began in 1971, and now attracts about 550 registrants each year. In Toronto, the annual dip has raised $300,000 for Habitat for Humanity since its initiation by 25 intrepid plungers in 2006. On January 1st, 2015, 564 swimmers entered the waters of Lake Ontario at Sunnyside Beach, despite a wind-chill of -29.5°C. In nearby Oakville, money is raised for World Vision, $1,201,000 since inception of the event in 1995; in 2014, 723 people entered the Lake.

The Netherlands initiated a similar ritual at the coastal resort of Scheveningen in 1960, and by 2012 there were an estimated 36,000 participants in polar bear events in various Dutch cities. In Scotland, a Loony Dook has been held at South Queensfery, in the icy waters of the Firth of Forth since 1986, and at Sandy Point State Park, MD, an estimated 12,000 people participate in the Plungapalooza.

Blessing of the waters. The Greek Orthodox Church throughout the world (including several congregations in Vancouver) celebrates the "Blessing of the Water" during the season of Epiphany (commonly, on January 6th). After celebration of the Eucharist, congregations adjourn to the sea or lakeshore, where the priest throws a cross into the water, marking the baptism of Jesus; younger members of the congregation then compete to see who can retrieve the cross (Watson 2013).

Ultra-long distance swims. Much of the early history of ultra-long distance swimming is detailed in a recent text (Shephard, 2015). Marathon swims in Lake Ontario became one of the attractions at the Canadian National Exhibition during the late 1920s, and in 1956 the 16-year-old Marilyn Bell swam the 56 km from Youngstown, NY, to Sunnyside in Toronto in a total time of 21 hr (Tivy, 2003). By 2014, 60 people had repeated her feat.

In 1875, Captain Matthew Webb was the first person to swim the English Channel without the aid of artificial buoyancy (Webb and Payne, 1999); it took him 21 hr 45 min to reach the French shore near Calais. By 2015, there had been 1832 one-way, 41 two-way, and 3 three-way crossings of the English Channel, with 8 deaths, and many other swimmers had abandoned their attempt (Klemperer and Thomas, 2014); moreover, the number of swimmers attempting the crossing has escalated rapidly since 1995, with 88 successful participants during 2014 alone.

Both Lake Ontario and English-Channel swims are usually made in the summer, when the water is a little warmer than that encountered by polar bear swimmers. The English Channel reaches a maximum temperature of 15°C, and the summer water temperature of Lake Ontario is often of a similar order. However, any advantage over the polar bear swimmers in terms of water temperature is negated by the much longer period of exposure.

Risks of cold-water immersion

The risks of cold-water events include the immediate hazards of cold shock, with initiation of a gasping reflex, ventricular fibrillation, and various long-term manifestations of body cooling. In ultra-endurance swimming there is also a risk of pulmonary oedema and a multitude of less serious complaints. Cheung et al. has estimated that 20% of cold-water immersion deaths occur from the immediate cold shock and a further 50% from cold incapacitation over the next 15-30 minutes (Cheung et al., 2003). The lowest core temperature of a person who subsequently made a full recovery was seen in a 10-yr-old Swedish girl, whose body temperature had reportedly dropped to 13.0°C (Radio Sweden, 17th January, 2011).

Cold shock. A cold-shock response occurs immediately on entering frigid water, and it can persist for as long as 2 minutes (Tipton, 1989). It is precipitated by an intense stimulation of cutaneous temperature receptors; this occurs at any water temperature lower than 25°C, but is maximal at a water temperature of around 10°C (Tipton et al., 1991). The body responds by gasping, and hyperventilation, making it difficult to hold or control the breath (Cabanac et al., 1964; Duffin et al., 1975; Mekjavić et al., 1987; Lin, 1988).

Poorly coordinated breathing can be particularly embarrassing if the individual concerned is in the course of a dive, with a potential for death by drowning. The inspiration of >22 $mL \cdot kg^{-1}$ of water is usually lethal (Modell et al., 1976), probably because the filling of the lungs with water causes a rapid cooling of the blood.

The hyperventilation associated with immersion may increase the immediate respiratory minute volume as much as tenfold, and it quickly causes hypocapnia (Keatinge et al., 1964), with a decrease of cerebral blood flow, disorientation and a loss of consciousness (Steinman 2001).

The cold-induced cutaneous vasoconstriction increases central blood volume, with tachycardia, hypertension, and an increase of cardiac work rates (Renson and Van Gerven, 1969; LeBlanc, 1975). This is exacerbated by a secretion of catecholamines (Johnson et al., 1977), and in a compromised heart it can contribute to cardiac arrest or ventricular fibrillation.

Ventricular arrhythmias. The increase in cardiac loading imposed by cutaneous vasoconstriction and the local shock caused by the arrival of very cold blood in the heart are compounded by a conflict between the sympathetically-mediated cold shock and the parasympathetically-mediated diving bradycardia. The resulting disarray of the autonomic nervous system may contribute to the high frequency of cardiac arrhythmias that are seen even in healthy volunteers when they are are suddenly immersed in cold water (Shattock and Tipton, 2012).

The tendency to arrhythmias during cold immersion is increased in older individuals with chronic heart disease (Schmid et al., 2009). Ventricular fibrillation beomes an increasing hazard if the body has undergone severe cooling (Lloyd and Mitchell, 1974; Vanden Hoek et al., 2010); it may be precipitated by rough handling during rescue. Asystole and fibrillation become increasingly likely as the core temperature drops below 30°C, although the cardiac contribution to late deaths in cases of near drowning has probably been over-stated (Lloyd, 1992).

Body cooling. Water is a good conductor of heat, and the body thus cools much more rapidly when it is immersed in cold water; the process of heat loss is accelerated by gasping and the inhalation of substantial volumes of cold water into the lungs (Golden et al., 1997).

Many of the chemical reactions in the body follow the Law of Arrhenius, halving in velocity with a 10°C decrease in temperature of the reactants (Arrhenius 1889). Thus, the speed of nerve conduction decreases by 15 m·sec^{-1} for each 10°C drop in tissue temperature, with total nerve block developing at a local temperature of 8-10°C (Vangaard, 1975). Likewise, the pressure and touch receptors in the skin have only a sixth of their normal sensitivity at a local temperature of 20°C, and their function ceases at 5°C (Irving, 1966). Shivering depletes body reserves of glycogen, with a progressive hypoglycaemia (Jacobs et al., 1985; Shephard, 1993), although in extreme cold, shivering mechanisms also9 are incapacitated. The maximal muscle force decreases rapidly at local temperatures of less than 27°C (Clarke et al., 1958), and the function of the muscle spindles ceases at 15-20°C (Stuart et al., 1963). The function of the brain deteriorates at temperatures below 35°C, and consciousness is lost at temperatures between 27 and 31°C (Cooper et al., 1964). Thermal regulatory mechanisms no longer function, and if the person is not recued death occurs at a body temperature of about 24°C.

If a person remains in cold water and the body temperature falls, functional ability gradually decreases, with a loss of manual dexterity, muscle cramping and a progressive degradation of the ability to swim, until death occurs from drowning or hypothermia. Prior to the 1950s, most cold-water deaths were attributed to drowning rather than hypothermia (Guly, 2011). An increased viscosity of the water at low temperatures further compounds the problems of cold-water immersion.

Opinions on the likely period of human survival in cold water have changed since the 1950s, when a figure of around 5 minutes was suggested for near-freezing water temperatures. On transatlantic flights during this era, BOAC flight attendants used to draw the attention of passengers to a small whistle that was attached to their flotation vests. They suggested that this whistle could be used to attract the attention of passing vessels in a heavy North Atlantic gale. The suggestion appeared even more ludicrous if survival times were indeed limited to around 5 min. However, the underlying data on survival were drawn from the observations of German physicians, made during the notorious experiments that were conducted on prisoners at the Dachau Concentration Camp in 1942 (Pozos, 2003). Apart from the moral issue as to whether such data should be considered at all, the findings plainly lack generalizability, since the concentration camp inmates were grossly emaciated, with a corresponding acceleration of their rates of body cooling. Earlier evidence from the sinking of the RMS Titanic found that survival of the 1489 passengers who were immersed in -2°C water ranged from 15 to 120 minutes. Likewise, studies on Canadian dinghy sailors of normal body build (Hayward et al., 1975) found survival times of over one hour. Thus, fatal body cooling is a potential issue for ultra-long distance swimmers, but is unlikely to be of concern to those involved in short polar bear swims.

Pulmonary oedema. Pulmonary oedema (manifested by shortness of breath, tachypnoea, cough, haemoptysis, and eventual hypoxic confusion) commonly develops with ultra-endurance swimming (Koehle et al., 2005; Adir et al., 2004). The causes are unclear; but one important factor is likely an increased central blood volume (due to a combination of cutaneous vasoconstriction and hydrostatic compression of the leg veins).

Other complaints of the long-distance swimmer. Other complaints of the ultra-long distance swimmer (Klemperer and Thomas, 2014) include seasickness, vomiting, a progressive loss of energy, salt mouth, jellyfish stings, eyelid irritation provoked by the swimmer's goggles, shoulder pain, boredom, sensory deprivation, and even entanglement with flotsam.

Counter-measures

Cold shock. Habituation can lessen the autonomic cold immersion response of both the skin and the body as a whole (LeBlanc, 1975; Golden et al., 1980; Tipton and Bradford, 2014). Thus, the extent of thhe initial cold shock can be reduced considerably by a combination of mental preparation and habituation (for example, the taking of cold showers each day for a week prior to the event (Eglin and Tipton, 2005). However, opinion is divided on whether it is better to dive straight in, or to enter the water slowly.

The person who is immersed in cold water should try to keep the head above the surface during the period when respiration is poorly controlled, and to avoid panicking (which is likely to increase hyperventilation and accelerate loss of consciousness).

Those with known arrhythmias or other cardiac conditions are best advised not to participate in cold immersion events. If arrhythmias do develop, lidocaine seems of little therapeutic help. Some authors have advocated treatment with bretylium (5 $mg{\cdot}kg^{-1}$), although a formal study in dogs found no advantage of either bretylium or amiodarone (10 $mg{\cdot}kg^{-1}$) relative to a placebo treatment (Stoner et al., 2003).

Body cooling. Organizers of cold water swimming events should ensure that warming tents, hot drinks and personnel competent in cardio-respiratory resuscitation are on hand. Alcohol not only impairs judgment, but also causes cutaneous vasodilatation, with an acceleration of body cooling; it should thus be scrupulously avoided. Safety is increased by an effective buddy system, or in the case of ultra-long distance events, regular surveillance from a pilot boat. Effective towelling and a change into dry clothes should be undertaken immediately on emerging from the water; much heat can be lost with wet clothes and a high wind. Those with significant hypothermia should be transferred quickly to a hospital with experience in treating this condition.

"Channel Rules" nominally prohibit the ultra-long distance swimmer from using any aids to heat retention such as a neoprene cap or wetsuit, although Captain Webb was said to be well smothered in porpoise grease (Webb and Payne, 1999). Modern swimmers often apply a thick layer of vaseline or lanolin; this is officially to reduce chafing of the skin, although it also substantially reduces the rate of heat loss (Pugh et al., 1960). Another potential tactic, helpful to both flotation and body cooling, but undesirable from the viewpoint of long-term health, is to increase body fat stores; the rate of heat loss is inversely proportional to the thickness of subcutaneous fat (Keatinge, 1960). Heat loss is directly proportional to body surface area; thus lanky individuals and children cool faster than those who are rotund. Posture and body movement markedly influences the rate of cooling.

Adoption of the fetal position minimizes the surface offered to the water and thus the rate of heat loss. In contrast, swimming disturbs the insulating film of water in immediate contact with the skin, and greatly increases the rate of heat loss (by 134% when treading water, and by 182% during a drown-proofing manoeuvre)(Hayward et al., 1975). Where possible, a person who is abandoning an event should get out of the water; heat loss is much more rapid in water than in air.

Other complaints. There are simple remedies for some of the other complaints of the ultra-long distance swimmer (Klemperer and Thomas, 2014). The salt mouth sensation is reduced by breathing through the nose, and the provision of a mouthwash and sweet foods at feeding breaks. Trimming of the eyelashes may reduce problems from the wearing of goggles. Shoulder pain can be addressed by adding small doses of ibuprofen or paracetamol to liquid foods as required. The accompanying crew can finally provide conversation and simple games at feeding times in order to minimize boredom and sensory deprivation.

Discussion and conclusions

Although the nature of the risks of cold-water events is now well documented, there is a lack of good evidence on the incidence of serious adverse events. This probably implies that incidents are relatively infrequent, but there is a need for a National registry to collect better statistics.

The main concern of the both polar bear swimmer and the Orthodox Christian "diving for the cross" is to overcome the immediate shock response to the cold water. With preliminary habituation and other swimmers at hand to offer assistance, the risk of serious complications is small.

Ultra-long distance swimmers face additional challenges, including most seriously the risks of pulmonary oedema and progressive hypothermia. Body cooling may impair both judgment and the ability to continue swimming, and an experienced supervisor (in a pilot craft) must monitor the condition of participants in such events frequently. British Swimming undertook an epidemiological survey of open water swimming in the years 2008 and 2009. A total of 28 adverse events were reported, a rate of 80 per 1000 swimming hours; 11 swimmers were rescued by their escorting craft, an incidence of 31 per 1000 swimming hours. The main issues were hypothermia, shortness of breath, water ingestion, chest pain, fatigue and cramp. However, events were seen mainly in the latter part of the swim; only one participant developed hypothermia over a distance of less than 2000 m.

Neither polar bear swimming nor ultra-long distance events claim any particular benefits for health, but on the other hand, given adequate supervision there seem no strong reasons to advise against participation by those wishing to face the challenges of cold water immersion events.

Author's Qualifications

The author's qualifications are Roy J. Shephard, C.M., M.B.B.S., M.D.[Lond.], Ph.D., D.P.E.,LL.D., D.Sc.

References

Adir, Y., Shupak, A., Gil, A., Peled, N., Keynan, Y., Domachevsky, L., et al. (2004). Swimming-induced pulmonary edema: clinical presentation and serial lung function. *Chest* 2004, 126(2) 394-399. PMID: 15302723.

Arrhenius, S.A. (1889). Über die Dissociationswärme und den Einflusß der Temperatur auf den Dissociationsgrad der Elektrolyte (On the heat of dissociation and the influence of temperature on the degree of dissociation of electrolytes). *Z. Physik. Chem.* **4**: 96–116.

Burr, J., Montelpare, W.J., and Shephard, R.J. (2013). Does adventure sport have a role in health promotion? *Can. Fam. Phys.,* 59(12), 1311-1313.

Cabanac. M.. A. Lacaisse. P. Pasquis and P. Dejours (1964). Caractères et mécanisme des réactions ventilatoires au frisson thermique chez I'Homme (Characteristics and mechanisms of ventilatory reactions to thermal shivering in man). *C.R. Soc. Biol. (Paris)* 158, 80-85.

Cheung, S.S., Montie, D.L., White, M.D., and Behm, D. (2003). Changes in manual dexterity following short-term hand and forearm immersion in 10 degrees C water. *Aviat Space Environ Med* 74(9): 990–3. PMID 14503680.

Clarke, R.S.J., Hellon, R.F., and Lind, A.R. (1958). The duration of sustained contractions of the human forearm at different muscle temperatures. *J. Physiol.(Lond.)* 143(3), 454-473. PMID: 13588567.

Cooper, K.E., Hunter, A.R., and Keatinge, W.R. (1964). Accidental hypothermia. *Int. Anaesthesiol. Clin*. 2(Aug), 999-1013. PMID: 14201476.

Duffin, J., Miller, R., Romet, T.T., Chant W., Ackles, K., and Goode, R.C. (1975). Sudden cold water immersion. *Resp. Physiol.* 23(3), 301-310. PMID: 1144945.

Eglin, C.M., and Tipton, M.J. (2005). Repeated cold showers as a method of habituating humans to the initial responses to cold water immersion. *Eur. J. Appl.Physiol.* 93(5-6), 624-629. PMID: 15778892.

Golden, F.S., Hampton, I.F., and Smith, D. (1980). Lean long distance swimmers. *J. R. Nav. Med. Serv.* 66(1), 26-30. PMID: 7420305.

Golden, F.S., Tipton, M.J., and Scott, R.C. (1997). Immersion near-drowning and drowning. *Br. J. Anaesthesia* 79(2), 214-225. PMID: 9349132.

Guly, H. (2011). History of accidental hypothermia. Resuscitation 82(1), 122-125. doi: 10.1016/j.resuscitation.2010.09.465.

Hayward, J.S., Eckerson, J.D., and Collis, M.L. (1975). Effect of behavioral variables on cooling rste of man in cold water. *J. Appl. Physiol*. 38(6), 1073-1077. PMID: 1141120.

Irving, L. (1966). Adaptations to cold. *Sci. Amer.* 214(1), 94-101. PMID: 5948081.

Jacobs, I., Romet, T.T., and Kerrigan-Brown, D. (1985). Muscle glycogen depletion during exercise at 9 degrees C and 21 degrees C. Eur. J. App-l. Physiol. 54(1), 35-39. PMID: 4018052.

Johnson, D.G., Hayward, J.S., Jacobs, T.P., Collis, M.L., Eckersman, J.D., and Williams, R.H. Plasma norepinephrine responses of man in cold water. *J. Appl. Physiol*. 43(2): 216-220. PMID: 911386.

Keatinge, W.R. (1960). The effect of subcutaneous fat and of previous exposure to cold on body temperature peripheral blood flow and metabolic rate of men in cold water. *J Physiol.* 153(1),166-78. PMCID: PMC1359738.

Keatinge, W.R., McIlroy, M.B., and Goldfien, A. (1964). Cardiovascular response to ice showers. J. Appl. Physiol. 19(6), 1145-1150. PMID: 14232311.

Klemperer, F., and Thomas, E.S. (2014). Captain Webb's legacy: the perils of swimming. BMJ 349, g7372, 1-5. doi: 10.1136/bmj.g7372.

Koehle, M.S., Lepawsky, M., and McKenzie, D.C. (2005). Pulmonary oedema of immersion. *Sports Med*, 35(3),183-190. PMID: 15730335.

LeBlanc, J. (1975). *Man in the cold*. Springfield, IL, C.C. Thomas.

Lin, Y.C. (1988). Applied physiology of diving. *Sports Med.* 5(1), 41-56. PMID: 3278355.

Lloyd, E.L. (1992). The cause of death after rescue. *Int.J. Sports Med*. 13(Suppl. 1), S196-S199. PMID: 1483774.

Lloyd, E.L., and Mitchell, B. (1974). Factors affecting the onset of ventricular fibrillation in hypothermia: a hypothesis. *Lancet* ii(7892), 1294-1296. PMID: 4139529.

Mekjavić, B, La Prairie, A., Burke, W., and Lindborg, B. (1987). Respiratory drive during sudden cold water immersion. *Resp. Physiol.* 70(1), 121-130. PMID: 3659607.

Modell, J.H., Graves, S.A., and Ketover, S. (1976). Clinical course of 91 consecutive near-drowning victims. *Chest*, 70(2), 231-238. PMID: 780069.

Pozos, R.S. (2003). Nazi hypothermia research: Should the data be used? *Military Medical Ethics Vol. 2*, 437-461. T.E. Beam (ed.). Washington, DC, Office of the Surgeon General.

Pugh, L.G.C.E., Edholm, O.G., Fox, R.H., wolff, H.S., Harvey, G.R., Hammond, W.H., Tanner, J.M., and Whitehouse, R.H. (1960). A physiological study of channel swimming. *Clin. Sci.* 19, 257-273. PMID: 14435266.

Renson, R., and Van Gerven, D. (1969). Afkoelingsreakties by Zwemmen in Koud Zeewater (Cooling reactions by swimming in cold sea water). *Hermas (Leuven)* 3, 191-218.

Schmid, J-P., Morger, C., Noveanu, M., Binder, R.K., Anderegg, M., and Saner, H. (2009). Haemodynamic and arrhythmic effects of moderately cold (22°C) water immersion and swimming in patients with stable coronary artery disease and heart failure. Eur. J. Heart Fail. 11, 903-909. doi:10.1093/eurjhf/hfp114.

Shattock, M.J. and Tipton, M.J. (2012). "Autonomic conflict;" a different way to die during cold water immersion? *J. Physiol.* 590 (Pt. 14), 3219-3230. doi: 10.1113/jphysiol.2012.229864.

Shephard, R.J. (1993). Metabolic adaptations to exercise in the cold: An update. *Sports Med.* 16(4), 266-289. PMID: 8248684.

Shephard, R.J. (2015). *An illustrated history of health and fitness, from pre-history to our post-modern world*. New York, NY, Springer.

Steinman, A. (2001). Cold water immersion. In: *Wilderness Medicine, 4th ed*. P. Auerbach (ed.). St.Louis, Mo, Mosby.

Stoner, J., Martin, G., O'Mara, K., Ehlers, J., and Tomlanovich, M. (2003). Amiodaraone and bretylium in the treatment of hypothermic ventricular fibrillation in a canine model. *Acad. Emerg. Med.* 10(3), 187-191. PMID: 12615580.

Stuart, D.E., Eldred, E., Hemingway, A., and Kawamura, Y. (1963). Neural regulation of the rhythm of shivering. In: *Temperature. Its measurement and control in science and in industry*. J.D. Hardy (ed.). New York, NY, Rerinhold, Vol. 3(3), p. 545.

Tipton, M.J. (1989). The initial responses to cold water immersion in man. *Clin. Sci. [Lond.}* 77(6), 581-588. PMID: 2691172.

Tipton, M.J., and Bradford, C. (2014). Moving in extreme environments: open water swimming in cold and warm water. *Extreme Physiol. Me*d. 3:12. doi:10.1186/2046-7648-3-12.

Tipton, M.J., Stubbs, D.A., and Elliott, D.S. (1991). Human initial responses to immersion in water at 3 temperatures and following hyperventilation. *J. Appl. Physiol*. 70(1), 317-322. PMID: 2010387.

Tivy, P. (2003). *Marilyn Bell: the heart-stopping tale of Marilyn's record-breaking swim*. Canmore, AL, Altitude Publishing.

Vanden Hoek, T.L., Morrison, L.J., Shuster, M., Donnino, M., Sinz, E., Lavonas, E.J., Jeejeebhoy, F.M., and Gabrielli, A. (2010). Part 12: cardiac arrest in special situations: 2010 American Heart Association Guidelines for Cardiopulmonary Resuscitation and Emergency Cardiovascular Care. *Circulation* 122(18 Suppl 3), S829–S861. doi: 10.1161/CIRCULATIONAHA.110.971069.

Vangaard, Z. (1975). Physiological reactions to wet cold. *Aviat. Space Envir. Med*. 46(1), 33-36. PMID: 1115693.

Watson, Leon (2013). Come on in, the water's lovely! Hundreds of Russian Orthodox Christians plunge into icy pool to celebrate baptism of Jesus. London, UK, *The Daily Mail*, January 19th, 2013

Webb, M., and A.G. Payne. (1999).*The art of swimming*. Whitstable, UK, Pryor Publications.