PUSHING THE BOUNDARIES

Swimmer and scientist perspectives on ice swimming: your questions answered



AUTHORS
E Jane Turner Department of Breast Surgery, Croydon University Hospital, UK
Mike Tipton Extreme Environments Laboratory, School of Sport, Health and Exercise Science, University of Portsmouth, UK
Mark Harper Department of Anaesthetics, Brighton and Sussex University Hospitals NHS Trust, UK
Kate Steels International Ice swimming Association Great Britain
Ruth Williamson Royal Bournemouth and Christchurch NHS Foundation trust, UK
Heather Massey Extreme Environments Laboratory, School of Sport, Health and Exercise Science, University of Portsmouth, UK

As the popularity of open water swimming continues to grow, so do the number of people 'pushing the boundaries' at the extremes of distance and temperature. We spoke to some leading experts on cold water swimming and gained some advice about the effects it has on the body, how to look out for signs of hypothermia and a few general pointers if you're contemplating taking on an ice mile or cold-water swim.

An ice mile is one of swimming's most extreme challenges. For an attempt to be successfully classified by the International Ice Swimming Association (IISA), rules state that swimmers must wear nothing more than a standard swimming costume, goggles and one swim hat to complete an unassisted mile swim in water that is 5 degrees Celsius or lower. For these reasons, ice swimming is not only extreme, but also dangerous. Nevertheless, those brave enough to successfully complete an ice mile claim their right to wear the uniform of a very exclusive club of extreme swimmers, the coveted ice mile Red Jacket.

If you're thinking about taking on an ice mile or are keen to swim in sub-5-degree water, here is some advice from our panel of experts on cold water swimming.

Glossary

Afterdrop: Following cold water immersion and on immersion in hot water, the deep body temperature continues to fall due to the thermal gradients which have been established.

Brown adipose tissue (BAT) thermogenesis: Also known as non-shivering thermogenesis. Increased metabolic production of heat by BAT in response to cold exposure

Cold water habituation: Attenuation of the cold shock and shivering responses

Cold shock response: Immediate, transitory response to immersion including inspiratory gasp, hyperventilation, tachycardia, hypertension and increased stress hormone response accompanied by autonomic conflict. A combination leading to risk of drowning.

Glycogen supercompensation: This is a window of time (up to two hours after the exercise, depending on the literature read) after activity in which the muscles more readily take up glucose and store as glycogen, ensuring greater stores in the muscle.

Hunting response: Also known as cold induced cyclic vasodilation. An alternating vasoconstriction and vasodilation in the peripheries exposed to cold typically occurring every 5 -10 minutes and most likely due to a decrease in local neurotransmitter release in response to the cold. It is thought to be protective to the digits. The response unfortunately may be minimised in acclimatised individuals.

Hypothermic adaption: A reduction in the metabolic response to cold (shivering) with greater reduction in deep body temperatures. Shivering won't occur at deep body temperatures that a swimmer has already been repeatedly experienced, an unhabituated response returning at temperatures lower than this.

IISA: International Ice Swimming Association

Insidious hypothermia: The undefended fall in deep body temperature where temperature falls too slowly to evoke a defensive reaction.

Insulative adaption: Decreased reduction in deep body temperature in response to lower skin temperatures due to vasoconstriction

Non-freezing cold injury (NFCI) affects the hands or feet due to exposure to wet conditions which are above freezing.

Swimming-induced pulmonary oedema: Pulmonary oedema related to immersion, where fluids from the pulmonary capillaries leak into the alveoli.

Key Points

1 Ice swimming should be considered an extreme sport and both swimmers and event organisers need to be aware of the physiology and risks.

2 Swimmers may have poor judgement about their thermal response to the cold.

3 Well adapted / acclimatised swimmers are still at risk. They may become hypothermic very suddenly as they may not shiver until they are already clinically hypothermic.

4 Entry to the water should be staged and a swimmer shouldn't start swimming until the peak cold shock response has passed.

5 The coldest point of a swim is after a swim.

6 Being fat and fast is advantageous, as is good pre and post swim nutrition.

7 Good technique is important but may suffer due to the environment.

Questions

1. What happens to the body on entering cold water?

When entering cold water the skin is immediately cooled and this is sensed by cold receptors very close to the skin surface. This results in an initial gasp, followed by rapid uncontrollable breathing, as well as an increase in heart rate and blood pressure and is also known as the 'cold shock response'. In one or two slightly larger than normal inhalations, it is possible to aspirate a lethal amount of water. In those with underlying heart conditions or high blood pressure the effect on the heart and circulation may lead to heart attacks. Therefore it is important that swimmers enter the water slowly, are over the peak cold shock response and able to control their breathing before starting to swim.

2. Why should a swimmer have a staged entry if they are already used to cold water? Won't this simply expose them to the cold for longer?

The advantage of staged entrance is that the peak cold shock response elicited from initial immersion in cold water will have subsided. Whilst there has been shown to be a permanence effect of cold-water habituation (where adaption to cold water leads to reduced cold shock and shivering responses), it is still advisable from a safety perspective to enter slowly to ensure that breathing is controlled and which reduces the risk of breathing in the lethal dose of water to drown.

3. What changes occur in the body during a swim in cold water?

Following skin cooling, the superficial tissues including muscles and nerves start to cool, eventually resulting in a loss of strength and coordination. The arms are particularly susceptible to cooling, to the point where swimmers may not able to coordinate a swimming action or effect a self-rescue. Changes to a swimmers posture in the water (a more vertical than horizontal body position) and more splashy stroke may be signs of muscle cooling.

Humans normally regulate the deep body temperature at 36.5°C to 37 °C. When swimming in cold water the next phase of cooling, following muscle cooling, is the deep body (core). As the deep body cools so does the brain; swimmers become more introverted, start to make errors, take longer to process instructions and slur their speech. These symptoms start to develop before the deep body is cooled to 35°C (the medical definition of hypothermia) and will continue to increase in severity with further cooling.

4. How can a swimmer tell that they are adapting to the cold?

Swimmers can reduce the cold shock response, with repeated immersions in cold water, meaning that they will hyperventilate less and are able to start swimming sooner as they will have control



Left: When entering cold water, the skin is immediately cooled and this is sensed by cold receptors very close to the skin surface. This results in an initial gasp, followed by rapid uncontrollable breathing, as well as an increase in heart rate and blood pressure and is also known as the 'cold shock response'.

of their breathing more rapidly. A swimmer would also know they are adapting as they would feel more thermally comfortable on repeated exposure to cold water and have a decreased amount of shivering when immersed in water of the same temperature for the same duration. In addition the temperature threshold at which shivering occurs is reduced (hypothermic adaption). This does mean that swimmers may cool rapidly, but will start to shiver vigorously when the new lower shivering threshold is reached. Therefore they will start to defend their deep body temperature closer to the medical definition of hypothermia (35°C).

5. In the field setting, what kind of thermometer might be used?

Outside of a laboratory environment, rectal temperature measurement might be considered to be a practical inconvenience, but tympanic thermometers are unreliable (and would likely give falsely low readings due to a wet external auditory canal). Oral thermometers are more acceptable than rectal, but will depend on the effect of water swallowed by the swimmer.

When measuring temperature, it is important to be aware that continued cooling 'afterdrop' will occur. This continued cooling may occur for some time after (possibly 30 minutes) resulting in the lowest deep body temperature occurring sometime following the swim (a time which will vary from one swimmer to another). If one is going to measure deep body temperature after a swim, taking regular repeated measurements is advisable.

6. How reliable are swimmers' subjective assessments of how cold they are becoming during a swim?

Whilst a swimmer may attempt to rely on the absence of clinical symptoms / signs of hypothermia as reassurance, evidence suggests there are difficulties with self-prescribed exposure, with cases of athletes swimming to unconsciousness and indeed death. Whether, this is due to overriding of thermally initiated drives to stop or absence of these drives is not understood. A disassociation of the thermal state of the body from subjective perceptions make swimmers' subjective assessments particularly unreliable. A swimmer may have a completely habituated shivering response, high levels of thermal comfort and a much faster fall in deep body temperature than would be expected from their body size and composition.

7. Is there any research suggesting safe cut off times for ice swimming?

There isn't the data at these low temperatures and even if there were, interpretation would be difficult due to the variation in body morphology, swimming speed and adaptive responses. A recent paper has attempted to suggest a cut off time, but this was at 10 degrees Celsius and with swimmers wearing wetsuits. Due to the large heterogeneity of swimmers and their thermal response, that cut off time was 30 minutes (Melau et al. 2019).
An ice mile taking 30 minutes will be at colder temperatures and without a wetsuit, so it has to be accepted that ice mile swimming is an extreme

sport with serious risks. Those providing medical supervision to such events should be aware that a degradation of swim technique usually proceeds general hypothermia and also recognize the early symptoms of hypothermia in swimmers: slow responses to questions being common early warning signs. They should also be aware that the temperature response to swimming is highly variable depending on the swimmers body composition. Consequently, the duration one swimmer can sustain themselves in cold water will be very different to another.

8. Is swimming with a full bladder or drinking warm water before getting in likely to make any significant difference to deep body temperature?

Swimming with a full bladder is not advised as that fluid will have no impact on the circulating volume or help with heat retention. Most swimmers experience increased urine flow (diuresis) in response to a combination of cold and water squeeze (hydrostatic pressure). However if the swimmer is not able to urinate and continues to drink, this may induce a swimming-induced pulmonary oedema (SIPE) where the fluid from the pulmonary capillaries leaks into the air sacs. .

Drinking warm fluids prior to entry into the water may have a psychological effect: A swimmer may feel better for having the warm drink or by warming the hands on the cup. However, when one calculates the change in temperature of the body resulting from the small amount of hot fluid added to the body's much larger volume of cooler fluid there are unlikely to be any physiological differences.

9. What is non freezing cold injury (NFCI) and who is at risk?

NFCI affects the extremities of the body including the hands or feet due to exposure to wet conditions which are above freezing. The blood flow to the affect parts of the body is blocked, causing the affected fingers or toes to go white, numb and can be painful. It can lead to long term debilitating symptoms. Not nearly enough is understood about it and researchers are not even clear if it is a nerve or vascular problem or a combination of the two.

Some people developed NFCI at water temperatures as high as 15 °C over a prolonged durations. Others believe that episodes occurred during short very cold exposures. Suffice it to say, the 'dose of cold' needed is not known, nor who is more susceptible to these conditions. What is known from studies in military populations is that people of African descent report a larger number of NFCI compared to white people, but it is unclear why/if the condition is just as prevalent in white people but under reported.

10. How would a swimmer know they were at risk of NFCI? What kind of symptoms would they have?

Ice swimmers are at risk, and there have been incidences where ice swimmers have developed non freezing cold injuries. A swimmer would have symptoms and although there is not enough data to support this, a swimmer might be reassured by an absence of symptoms. NFCI is generally characterised by 4 stages:

The first stage: During cold exposure, the key finding is loss of sensation. This usually takes the form of complete anaesthesia. Patients complain of "numbness," sometimes describing feet or hands as feeling like a block of wood. Due to this loss of sensation and proprioception, patients may become clumsy and may have difficulty walking. Extremities may be bright red at first but then become pale or completely white due to extreme vasoconstriction (no blood flow to the digit). The extremity is usually painless unless rewarming is attempted. Allowing a slow rewarm, not forced, is advised.

The second stage: Following cold exposure begins as soon as the patient is removed from the cold environment and continues during and after rewarming. This stage usually lasts just a few hours but may persist for as long as several days. The extremities become a mottled pale blue, reflecting a slight increase in blood flow. The colour change can be hard to see in darkly pigmented skin. The extremity continues to be cold and numb. Some swelling can occur.

The third stage: The affected extremity becomes bright red and swollen with bounding pulses but

poor filling of the small blood vessels (capillaries) which are permanently damaged. Numbness from stage 2 is replaced by severe pain but with residual fingertip numbness. Although there is no obvious tissue damage, blistering can occur and subsequently change colour before permanent tissue breakdown occurs.

The fourth stage: The swelling may end after a few weeks, persist for years, or be permanent. The affected extremity usually appears normal, unless there has been tissue necrosis, which is uncommon. Affected extremities are cool and are often very sensitive to cold. Hands and feet can have poor blood flow after even a brief exposure to cold remaining cool for hours after a brief exposure. Most patients have chronic pain with small numb areas. Some patients may have long term problems with excessive sweating or complex regional pain symptoms.

11. What is the hunting response?

This is an alternating constriction and dilation of the blood vessels in the peripheries on exposure to cold typically occurring every 5 -10 minutes. It may explain why periodically a swimmer's fingers and toes warm up and then cool again when exposed to cold. It is thought to be protective against cold injury, but is reduced as the deep body (core) temperature drops. The effect is also reduced in people with good cold acclimatization.

12. Are there ways to help with production of heat (thermogenesis) and prevent loss of heat (insulation)?

The body operates by using the heat balance equation: in order to stay warmer for longer, one needs to increase heat production, by shivering or exercising harder or by insulating the body. Being fitter will allow exercise at higher intensities for longer. Feeding regularly will mean one can maintain the activity for prolonged periods whilst minimising fatigue. Heat loss externally can be manipulated by increasing body fat, but there potentially health implications to this and a swimmer may not wish to put on weight. Investigating the fat distribution and fat patterning profiles in swimmers may be of interest, for instance, where are the fat stores held, are they typically under the skin either on the hips or the legs, around the arms, abdomen or around the organs.

13. Should a swimmer drive after an ice swim is finished?

Cool muscle and nerves following the swim produce less power and take longer to perform the response required. In addition, a swimmer may have a lower deep body temperature consequently due to afterdrop. The combination of the two means that the response to a hazard whilst driving may be slower than usual and may place the swimmer and others at risk. Therefore, if a swimmer needs to leave before they are recovered, it is recommended that someone else does the driving.

14. Can a swimmer lose some of their adaption by using a sauna?

The lowest deep body temperatures will normally occur after the swim, during the afterdrop period. As the deep body tissues are not immediately rewarmed when entering the sauna. Using a warm (not hot) sauna to fully rewarm the deep body tissues requires the swimmer to remain in the warm room for a long time. This method rewarms the skin first, then the superficial tissues of the body, before rewarming the deep body tissues. The sauna takes a while to influence the deep body temperature so it is unlikely to affect the adaptive responses to cold water swimming which occurs as a result of the cold deep body temperature.

15. If fortunate enough to have a sauna or warm room, how long should a swimmer stay in?

Cold water swimmer who have access to a warm (not hot sauna) should stay in the sauna long enough to ensure their deep body is rewarming (after the afterdrop), but not too long that they start to sweat.

A good way to assess this is by squeezing your finger tip quite hard, once you let go, if skin rapidly

returns to its normal colour, you are ready to get out. If your skin take time to return to its normal colour you have not rewarmed yet and can stay in a little longer.

Shorter durations in the sauna will warm the skin, but not allow for deep body rewarming. Quite frequently, swimmers will warm the skin, stop shivering and feel better, but not have rewarmed the deep body. If they leave the warm room at this stage, once the skin has cooled again, they may start to shiver. A warm, not hot sauna takes longer to rewarm, but with less chance of rewarming collapse which can be associated with rapid rewarming methods such as hot tubs or showering.

16. Why do the legs remain cold so much longer than the arms after a swim?

Many of the muscle of the shoulder and arms are active during swimming. This muscular contraction generates heat within the muscle. Active muscles also require a blood supply which will help to maintain a higher temperature in the surrounding tissues. Therefore the arms may not get as cold as the less active legs (that may also have a smaller blood flow). The lower limbs also have a greater tissue mass so will take longer to warm. The lower limbs may have a poorer blood supply than the upper arms for much longer after swimming. The key is to get the whole body dry and warm and dry, rather than preferentially rewarm a particular body part.

17. Is there any further guidance for those supervising ice mile events?

There should be a good understanding of the physiology of cold water immersion and adaption and the pathophysiology of the clinical problems encountered during events. Guidance needs to incorporate prevention and preparation before, during and after the event.
Before the event organisers need to screen swimmers for fitness and training adequacy as well as to consider the environment and support. The focus should be on effectiveness at reducing the incidence of potentially preventable incidents. They need to ensure that swimmers are fit.

The IISA regulations apply worldwide and include a medical assessment including ECG within 6 months of an IISA ratified ice mile. The key issues are family history of untoward cardiac events or significant risk factors. Cold shock causes a significant rise in blood pressure so a normal blood pressure should be confirmed. ECG allows screening for some risks of arrhythmia (irregular beating of the heart) and can indicate risks of heart attack or signs of heart muscle overgrowth, or weakness. Cardiomyopathy.

Some sports events (including ice swims) require a medical check-up, it is up to the doctor's discretion as to what is required to satisfy them that the swimmer is medically fit, or not, to participate. Greater awareness amongst medical professionals about the stresses of cold water and ice swimming, in particular, should be encouraged so that they can adequately assess the medical risk. However, it needs to be understood that there are limits to medical screening. Therefore, it is incumbent on the swimmer to accurately self-report medical information and non-disclosure to the doctor may result in significant harm, if swimmer is assessed as fit to participate in such events, when given the full history they would be withdrawn. If you are a Medical doctor and would like to learn more about the effects of cold water on the body, please get in touch.

In addition, swimming experience levels need to be considered. It should be questioned whether a single observed swim is enough, rather than a logbook of swims showing a repertoire of experience, which also indicates how recovery progressed.

Adequate safety cover at such events is essential. The safety team need skills, ideally immediate life support to provide prehospital care to swimmers before removal to hospital.

During the event, prevention is better than treatment, with trained and experienced observers empowered to make the call to pull swimmers showing signs of distress. There should be a clear chain of command for calling the end of a swim and an evacuation plan.

After the event, collecting information is key to improving and developing the safety



Above: Adequate safety cover at Ice Mile events is essential. The safety team need skills, ideally immediate life support to provide pre-hospital care to swimmers before removal to hospital.

documentation of the sport. At the moment only information on the number of successful ice mile attempts are recorded. At present there is no information collected on unsuccessful attempts, nor the reason for the termination of the attempt. Recording this information will help local organisers, support staff and administrators of the sport to accurately assess the risk, mitigate those risks, learn where mistakes were made and subsequently develop the safety record of the sport. Without this joined up approach, we cannot learn from others and may make some of the same mistakes.

18. We already know that cold water immersion will result in a reduced blood flow to the periphery. Does the swimming action affect this?

Swimming results in perfusion of the muscles. Moving through the water faster will prevent the warm boundary layer of water forming close to the skin surface, therefore increasing the gradient for heat loss. In addition, exercising the arms and legs increases heat production, but also blood perfusion of the muscle, therefore moving the blood away from the deep body to the periphery where heat can be more easily lost to the cold water. It is an interplay of factors, and comes down to heat balance, moving the arms more quickly, will increase heat production in the working muscles, but also results in increased blood perfusion in the muscle increasing the opportunity for heat loss. So, the question really depends on the insulation the muscles in the arm have to retain the heat generated within the body.

Once the person starts to tire, they will slow down and heat production in the working muscles is reduced. The blood flow to the fingers may be shut down, but not the arms, however, once the deep body starts to cool, the peripheral blood vessels will also shut down. If blood flow to the working muscle is reduced fatigue will continue to develop. Therefore, it is better to work at a pace which can be maintained and hopefully maintain heat balance for the duration of the swim, rather than start too quickly, fatigue and cool rapidly.

19. What are the main sources of energy used when swimming in very cold water?

The main sources of energy used are glucose and glycogen. Average swimmers have a large fat reserve but can only access it if they have sugar to help metabolize it (fat burns in a carbohydrate flame). It's been shown that there is a switch to fat metabolism whilst shivering when compared to exercise at the same intensity (Tipton et al. 1997). Faster swimmers will use less fat than slower swimmers due to differences in the maximal rate of energy generation (required for muscular contraction) from different fuel sources. Replenishing glycogen as soon as possible after the swim (especially if swimming the next day) is advised, ideally within 2-4 hours of the swim will result in 'glycogen supercompensation' an increase in muscle and liver glycogen stores to greater levels than before .

20. International Ice Swimming Association (IISA) say that swimming speed is approximately 20-30% slower than at pool temperatures (typically 28 degrees Celsius). What physiological factors are involved?

Muscle temperature will be lower as will nerve conduction, the arms being particularly susceptible when exercised in cold water leading to muscle fatigue. There is a fall in maximal aerobic capacity with decreasing deep body temperatures with resulting decreased VO2 max and cardiac output. Cooled muscle will use anaerobic means to produce energy at lower thresholds, leading to depletion of glucose and glycogen and earlier accumulation of lactate. Increased muscle tone (or frank shivering) will lead to less efficiency.

21. How does temperature and salinity affect density? And how does this affect your swimming?

The density of seawater increases with increasing salt content and decreases with increasing temperature. On average, the relative density of the human is 0.985 g.cm-3 (0.945 g.cm-3 on inhalation), which is lower than both fresh water at 1.0 g.cm-3 and salt water at 1.025 g.cm-3. As a result, the average body is 3.5% less dense than fresh water and 6% less dense than salt water. Therefore, an individual's ability to float is optimal in cold sea water, due to the greater density of the water in comparison to the density of the human body. So in sea water you may be able to adopt a body position with the legs close to the surface of the water (more streamlined) than you do in fresh water.

Water resistance increases with lower water temperature and will slow the speed of movement through the water more than assist with greater pulling power. However, one cannot consider this alone as physiologically, fatigue and changes in technique as a consequence of cooling will have a larger impact on performance when swimming. This performance issue will result in a less efficient body position, in greater drag and ultimately an inability to swim (swim failure). This is illustrated in the last part of this video of Mike Tipton when he was a little bit younger and Sharon Davis and Duncan Goodhew were still elite swimmers: https://www.youtube.com/watch?v=_96YEPAdA2Y

22. What is the best body type for cold water swimming?

Fat is most useful, it helps to insulate from the cold. Cold water and ice swimmers are generally slightly larger than average apart from a few very fast swimmers. Faster swimmers also have good technique which is well maintained (preventing the increase in drag), a high level of fitness with high heat generation to offset the cold water. Again, this comes down to heat balance, but also to good basic technique, fitness and insulation to reduce heat loss. Muscle will help with heat generation but is not as useful as fat. A tall muscular swimmer with a good amount of adipose tissue will produce a lot of heat, which they are able to retain in their body .

Lynne Cox describes in her memoir, Swimming to Antarctica, how she became a human research subject with physiologists noting her perfectly balanced fat to muscle proportions resulting in good body positioning and has been open about her body mass index being in the obese range (BMI 34) with body fat levels around 40 percent. In general, swimmers who do well in ice swimming competitions or ice miles tend to be lean and fast, fatter and fast, or fatter and slow, you don't tend to find lean slow cold water swimmers.

23. Do brown adipose tissue (BAT) help to keep swimmers warm?

There is evidence that BAT is activated by cold water immersion and suggestions that brown fat deposits may increase with cold acclimatization. The contribution of BAT to heat production is relatively small in comparison to increased muscle tone and shivering. If a swimmer is acclimatized they are likely to be more thermally comfortable and have a hypothermic adaptation, where deep body temperature falls without shivering to maintain it. Only once the deep body temperature falls to a level that is unfamiliar does overt shivering to defend deep body temperature occur. There can be undetectable shivering in the form of increased muscle tone or stiffness even if obvious shivering is not present.

24. What can be done to prevent fingers spreading?

Finger spreading is an indication that the swimmer should consider exiting the water. The likely cause is forearm muscle and nerve cooling, which causes a deterioration in the coordinated action of the swimming stroke. Having insulation (wetsuit, great fat layer) over the arms and forearms can reduce the heat lost from the muscles, but just as we can't choose where we lose fat from, we also can't choose where we store fat. Experimenting with ways to increase heat production, such as increasing the amount of kicking (to generate heat, and have more heat loss from the legs as opposed to the arms) is worth trying, bearing in mind that kicking is tiring and more difficult to sustain.

25. Is there an ideal stroke rate for an ice mile?

A consistent technique and therefore stroke rate is more important. Clearly there are ranges of stroke count which are optimal, somewhere between 50-70, with a hip driven rotating action. If a swimmer has an efficient technique they will need fewer strokes to move through the same distance.

There is a wide variation of stroke rates for the faster swimmers and this will vary with body size etc. A tall swimmer would probably would expect a slower stroke rate with longer stroke length. However, efficiency and technique are most important, stroke rate being secondary to these.

References

Daanen HA1, Van de Linde FJ, Romet TT, Ducharme MB (1997). The effect of body temperature on the hunting response of the middle finger skin temperature. Eur J Appl Physiol Occup Physiol.;76(6):538-43.

Melau J, Mathiassen M, Stensrud T, Tipton M, Hisdal J (2019). Core Temperature in Triathletes during Swimming with Wetsuit in 10OC cold water. Sports 7, 130.

International ice swimming association (IISA) regulations: https://www.internationaliceswimming.com/wp-content/uploads/2018/10/IISA-Swimming-Rules-and-Regulations.pdf

Tipton, M. J., Franks, C. M., Meneilly, G. S. & Mekjavic, I. B. (1997). Substrate utilisation during exercise and shivering. European Journal of Applied Physiology 76(1): 103-108.

Cox, L. Swimming to Antarctica. Tales of a Long Distance Swimmer. Weidenfield & Nicholson 2005.



Outdoor Swimmer is an independent monthly magazine dedicated to swimming outdoors. If you are passionate about swimming outdoors, then Outdoor Swimmer is the magazine for you. Each issue of Outdoor Swimmer is a celebration of swimming outside. There are inspirational stories, wild swimming spots, technique advice and stunning photography. Every issue also includes nutrition, training plans for beginners and experienced swimmers, events, wildlife, destinations, interviews and the latest outdoor swimming news.

Digital subscriptions: pocketmags.com/outdoorswimmer-magazine

Print subscriptions: mymagazinesub.co.uk/outdoor-swimmer