International Journal of Aquatic Research and Education

Volume 7 | Number 2 Article 9

2013

Appropriate Water Temperatures in Which to Conduct American Red Cross Aquatic Instructional Programs

American Red Cross Scientific Advisory Council

Recommended Citation

Scientific Advisory Council, American Red Cross (2013) "Appropriate Water Temperatures in Which to Conduct American Red Cross Aquatic Instructional Programs," *International Journal of Aquatic Research and Education*: Vol. 7: No. 2, Article 9.
DOI: https://doi.org/10.25035/ijare.07.02.09
Available at: https://scholarworks.bgsu.edu/ijare/vol7/iss2/9

International Journal of Aquatic Research and Education, 2013, 7, 167-178

International Journal of
Aquatic Research and Education
www.IJARE-Journal.com
SCIENTIFIC REVIEW

Appropriate Water Temperatures in Which to Conduct American Red Cross Aquatic Instructional Programs

Editor's Note: This print version of the scientific review, "Appropriate water temperatures in which to conduct American Red Cross Aquatic Instructional programs," was abbreviated due to space limitations in the print journal. The complete version of this scientific review including all the cited references and the summary of each is published in the online issue at http://journals.humankinetics.com/IJARE.

Questions to be Addressed

- What is the appropriate safe temperature-range for conducting ARC aquatic programs?
- Are safe temperature ranges different for head-in vs. head-out immersion activities?
- What variables exist that affect temperature ranges?
- What associated variables should be considered in modifying the suggested range?

Introduction/Overview

Water temperature is a major factor in participant comfort and overall success of an American Red Cross Aquatic Instruction programs. Water that is too cold can lead to chilling and discomfort and result in limiting the time spent on necessary learning practice. The American Red Cross currently references the Aquatic Exercise Association (AEA) guidelines for water temperature stating "a comfortable water temperature for swim classes is between 83° to 86°F (28.3° to 30°C)." These guidelines have recently been revised and updated for 2010. The current recommendation given for children's swim lessons is 84°F / 28.9°C. The range that is listed as "ideal" for a "Learn to Swim (LTS)" program is from 84-89°F or 28.9- 31.7°C. The range of water temperatures recommended for infant/ pre-school (ages 4 and under) programming is 90-93°F or 32.2 -33.9°C.

The AEA guidelines also include a statement that suggests that these guidelines may not be appropriate for every program. For example, it is an accepted fact that "young children are more susceptible to hypothermia than older children" (ARC p.148). Red Cross recommends that if water and air temperatures cannot be maintained within acceptable ranges, the lesson needs to be shortened or even postponed. These statements show recognition that there is a direct relationship between water temperature and time / duration of the lesson but there is little guidance beyond these reference statements.

In addition to age of the participant and duration of the lesson, temperature ranges may also need to be adjusted based on the type of programming. What this means for American Red Cross LTS programs is what levels are being offered and whether participants will be able to maintain a level of activity that supports thermoregulation. Keeping participants active or active enough to stay warm is not always possible with every level. Limitations might include the size of the practice area, children who do not possess enough skill to keep moving, or classes that are so large that participants stand around waiting for a turn. Any of these scenarios may require an adjustment to the water temperature recommendations.

And then there are programs that truly operate outside the norm for LTS programs ("norm" meaning the program structure currently recommended in the Water Safety Instructor Manual). Therefore, it is the purpose of this review to confirm the recommended temperature ranges provided by AEA and USA Swimming, to identify significant variables that affect thermoregulation, and to provide more guidance where temperature extremes are the norm or program types and structure vary widely.

Review Process and Literature Search Performed

On line search primarily used Pubmed and Google scholar

Pubmed searched for studies using variations of the following concepts: cold water immersion, thermoregulation, thermal balance, immersion hypothermia, temperature regulation, swimming and water temperature. We found 116 articles and rejected 41 of these as not relevant to the question.

We also searched the following print resources including

2010 USA Swimming Rules and Regulations (rule 103.6)

American Red Cross Water Safety Instructor Manual

Aquatic Exercise Association (AEA) 2010 Standards and Guidelines Aquatic Fitness Programming

Criteria for Considering Studies for this Review

- Only human studies (no mechanical models)
- Swimming research with reference to water temperature and intensity of exercise
- Immersion to at least the middle of the sternum (head-in full immersion preferred but not required)

Definitions Relevant to the Discussion

(from Bligh, J., & Johnson, K.G. (1973). Glossary of terms for thermal physiology. Journal of Applied Physiology, 35(6): 941-961)

Acclimation: A physiological change, occurring within the lifetime of an organism, which reduces the strain caused by experimentally induced stressful changes in particular climatic factors.

Acclimatization: A physiological change, occurring within the lifetime of an organism, which reduces the strain caused by stressful changes in the natural climate.

Area Total Body (Aρ): The area of the outer surface of the body assumed smooth. [m2]

Body Heat Balance: The steady-state relation in which heat production in the body equals heat loss to the environment.

Critical Temperature, Lower: The ambient temperature below which the rate of metabolic heat production of a resting thermoregulating animal increases by shivering and or non-shivering thermogenic processes to maintain thermal balance.

Critical Water Temperature (Tcw): the lowest water temperature in which a human subject can be immersed to the neck for a period 3 hours without shivering.

Fever: A pathological condition in which there is an abnormal rise in core temperature (Tc). The temperature rise in an individual may be considered as fever when it is greater than the mean SD for the species in basal condition.

Habituation: Reduction of responses to or perception of repeated stimulation.

Heat Storage, Change In: The gain or loss of heat associated with change in body temperature or body mass.

Homeothermy: The pattern of temperature regulation in a tachymetabolic species in which the cyclic variation in core temperature, either nychthermally or seasonally, is maintained within arbitrarily defined limits (±2°C) despite much larger variations in ambient temperature.

Hypothermia: The condition of a temperature regulating animal when the core temperature is more than one standard deviation (1 SD) below the mean core temperature of the species in resting conditions in a thermoneutral environment.

MET: an assigned unit of measurement to designate "sitting-resting" metabolic rate of humans. 1 MET = 58.15 W·m-2 = 50 kcal·h-1·m-2. It is an empirical unit of measurement to express the metabolic rate of a human whose clothing has an insulative value of 1 CLO when s/he is sitting at rest, in comfortable indoor surroundings (21°C).

Metabolic Free Energy Production (M): The rate of transformation of chemical energy into heat and mechanical work by aerobic and anaerobic metabolic activities within an organism, usually expressed in terms of unit area of the total body surface area.

Metabolic Heat Production (H): Rate of transformation of chemical energy into heat in an organism, usually expressed in terms of unit area of the total body surface.

Metabolic Rate (MR): MR may also be given as the total free energy production in the organism in unit time [W] or as the free energy production per unit mass of tissue in unit time [W·kg-1].

Metabolism: is a general term which relates to chemical and physical changes occurring in living organisms. In thermal physiology METABOLISM invariably relates to the transformation of chemical energy into free energy.

Temperature, Ambient (Ta): The average temperature of a gaseous or liquid environment (usually air or water) surrounding a body, as measured outside the thermal and hydrodynamic boundary layers that overlay the body [°C].

Temperature, Core (Tc): The mean temperature of the tissues at a depth below that which is affected directly by a changing the temperature gradient through peripheral tissues. Mean core temperature cannot be measured accurately, and is generally represented by a specified core temperature, e.g., that of the rectum (Tre) [°C].

Temperature, Mean Body (Tb): The sum of the products of the heat capacity and temperature of all the tissues of the body divided by the total heat capacity of the organism. Note: This heat capacity cannot be determined precisely in the living organism. Mean body temperature can be estimated approximately from measures of skin (mean skin temperature (Tsk) and core temperature (Tc).

Temperature Regulation: The maintenance of the temperature or temperatures of a body within a restricted range under conditions involving variable internal and /or external heat loads.

Temperature Regulation, Behavioral: The regulation of body temperature by complex patterns of responses of the skeletal musculature to heat and cold which modify the rates of heat production and/or heat loss (e.g., by exercise, change in body conformation, and in the thermal insulation of bedding and (in man) of clothing, and by the selection of an environment that reduces thermal stress).

Thermal Comfort: Subjective satisfaction with the thermal environment.

Thermal Conductance, Tissue: The rate of heat transfer per unit area during steady state when temperature difference of 1°C is maintained across the tissue. Note: this term relates to heat transfer down a temperature gradient from any tissue to its immediate environments, e.g., from a tissue to circulating blood as well as from the body core through peripheral tissues of the body surface.

Thermal Conductivity (k): A property of the material defined by the flow of heat by conduction through unit thickness of the material per unit area and per unit temperature difference maintained at right angles to the direction of heat flow.

Thermal Stress: Any change in the thermal relation between an organism and its environment which, if uncompensated by a temperature-regulatory response, would disturb the thermal equilibrium.

Thermogenesis, Shivering: An increase in the rate of heat production during cold exposure due to increased contractile activity of skeletal muscles not involving voluntary movements and external work.

Thermoneutral Zone (TNZ): The range of ambient temperature within which metabolic rate is at a minimum, and within which temperature regulation is achieved by non-evaporative physical process alone [°C]

Scientific Foundation

Much research has been done on immersion hypothermia, survival rates, and safety measures. These will not be reiterated in this work.

https://scholarworks.bgsu.edu/ijare/vol7/iss2/9
DOI: https://doi.org/10.25035/ijare.07.02.09

Thermoregulation. Human beings, as all warm blooded animals, maintain core temperatures (Tre or Tc) within a very narrow range. The average core temperature of a human is around 37°C (98.6°F) and body temperature extremes are demonstrated as a fever at 37.7°C (100°F) and when the mean body temperature falls to approximately 35.4°C (95.7°F) (20) just slightly more than 2°C. Therefore, our ability to regulate body temperature is critical for life safety and comfort.

Thermoregulation depends on the dynamic balance between heat gained (or generated) and heat lost to the environment. When a thermal stress is imposed on a human body, it reacts with a combination of metabolic and cardiovascular adjustments to maintain thermal comfort. The basic patterns of cold regulation include heat production by shivering and vasomotor responses which transfer heat down a thermal gradient from core to skin and then from skin to the environment. Vasoconstriction is a cold defense reaction that helps conserve heat by restricting blood flow to the periphery. When peripheral responses have been maximized, humans must either add insulation or rely on their ability to increase metabolism.

General responses to cold stress, whether in air or water, are similar in nature. However, resistance to the flow of heat energy is lower in the water as compared to air and becomes much lower when the skin and/or water are in motion. This makes temperature regulation during immersion more challenging than in air (29, 45, 47, 48).

The most comfortable temperature for a person at rest is referred to as "thermoneutral". This is the temperature at which unprotected man, at rest, will neither lose nor gain heat. Thermoneutrality in air is around 22.2°C (72°F)(19). An equivalent water temperature would be around 33°C (91.4°F). Cannon and Keatinge (1960) call this the "theoretical critical temperature," where humans "could, in theory, achieve thermal stability without an increase in metabolic rate . . ." (p. 338). Craig and Dvorak (1966) suggest that a neutral water temperature, (demonstrated by a mean body temperature that is the same at the beginning of an hour of immersion as at its conclusion) would have to be 34.6°C (94.2). Sagawa et al. (1988) confirm these findings. They reported thermoneutrality for their subjects as a water temperature of 34°C.

Comparing Research. Research involving human response to cold immersion is plentiful and in general seeks to establish different critical temperatures using a variety protocols. Because direct measurement of the hypothalamic temperature is not possible, other interactions must be used (6). The selection of measurements and the variety of combinations makes it difficult to compare results.The most common temperature measurements include core temperature (rectal temperature and sometimes esophageal temperatures in adults), esophageal and tympanic temperature (in younger adults and children), skin temperature, mean body temperature, subcutaneous fat thickness, surface area to mass ratio and a variety of metabolic responses including VO_{2max} and metabolic rate.

Comparing research is further complicated because of differences in methodology. Studies differ with the temperature of the water, duration of exposure, depth of immersion (head-out, head-in, chest deep, to the first thoracic vertebrae), body position (vertical, semi recumbent, horizontal) and type of and intensity of exercise (assuming that an exercise protocol is used). It is therefore prudent to proceed with caution when trying to compare results.

The most common water temperatures used to study an unprotected subject at rest during head-out immersion include 15°C (9, 35, 36, 41, 71, 72), 18°C (4, 16, 24, 25, 63), 20°C (8, 9, 23, 38, 42, 43, 71, 72), 25°C (8, 9, 32, 36, 39, 41, 69), 26°C (12, 16, 24, 65), 28°C (12, 39, 42, 43, 62, 71, 72). From these studies, certain general statements can be made. The following are generalized responses to water immersion in temperatures ranging from 15°C to 33°C:

- There is a direct relationship between water temperature (Tw) and the length of time a person can be comfortably immersed (7, 12, 26, 34, 37, 39, 53, 65,75). (As would be expected, when water temperature decreases, the duration of comfortable immersion also decreases.)
- Metabolic rate increases as the temperature of the water decreases (7, 8, 16, 24, 32, 57, 62). (Shivering is similar to light exercise which increases the metabolic rate).
- The range of water temperatures in which man can attain thermal balance can be extended by reducing the total surface area exposed to the water, by exercise (9, 13, 32, 36, 43, 44, 50, 57, 65) and by adding clothing (10, 22, 29, 34, 36, 51, 52,73).
- Head submersion increases the cooling rate of the body (22, 28, 39, 52, 62, 69).
- If water temperature and duration of immersion are controlled, there are a number of factors that act in concert to extend or reduce thermal comfort. These include but may not be limited to surface area to mass ratio(14, 25, 26, 28, 38, 39, 44, 59 61, 63), subcutaneous fat thickness (3, 4, 7, 8, 9, 16, 24, 25, 28, 34, 35, 38, 42, 44, 49, 53, 54, 59, 60, 62, 64, 65, 69) , age (10, 15, 18, 23, 40, 59, 62, 63, 71, 72, 73), sex (28, 37, 39, 40, 42, 43, 55, 59, 63, 71), rest vs. exercise (9, 26, 28, 32, 41, 45, 49, 65), level of fitness (15, 34, 40), and possibly acclimation (55).
- The type and intensity of exercise in the water affects the cooling rate of the body. (walking, cycling, rowing, swimming, arm ergometer are examples that appear in these protocols) (9, 11, 13, 20, 26, 28, 29, 36, 41, 47, 58, 67).
- The ability of the arms to retain heat is lower than that of the legs due to the higher surface area to mass ratio. Arms have approximately two times the SA/mass ratio as the legs (9, 26, 64, 67). (The majority of recognized swim strokes require higher levels of work from arms than legs even at similar workloads. (26, p404).
- There is a direct, nonlinear relationship between percent body fat (%BF) and critical water temperature (Tcw) (Persons with greater % BF have a lower Tcw and therefore can remain longer in the water with less cold stress)(3, 4, 7, 8, 9, 16, 24, 25, 28, 34, 35, 38, 42, 44, 49, 53, 59, 60, 62, 64, 65).
- Performance is affected by water temperature extremes. (46, 47, 50, 64)
- It is apparent from these studies that certain temperatures are well outside the range of comfort and therefore inappropriate for swimming instruction. Thus it becomes necessary to find a narrower range for thermal comfort. This can be accomplished by first looking at water temperatures that illicit little or no cold stress responses (head-out, at rest) and work to identify a range of temperatures

DOI: https://doi.org/10.25035/ijare.07.02.09

appropriate for swimming (head- in) and learning to swim at different levels of intensity and for durations appropriate for LTS programming.

The Lower Limits of Thermal Comfort. A number of studies have used a three hour immersion (head-out) protocol to established "critical water temperature (Tcw)", defined as the lowest water temperature that an unprotected subject can tolerate at rest without shivering. Sagawa et al. (1988) studied 6 men immersed to the neck (%BF not given) and found Tcw to be 31.2±0.5°C. Ferretti et al. (1988) also used a 3 hour immersion protocol to establish an individuals' Tcw and then used Tcw - 6°C to study the effect of exercise (head out immersion) on thermoregulation. Park et al. (1984) established Tcw for their subjects at between 28-32°C before looking at body insulation as it relates to exercise in cool water. Iwamoto et al. (1988) used a 2 hour protocol to establish Tcw. Critical water temperature was established at 32±0.4°C for 9 healthy men with 15.3± 1.2% BF. Bullard and Rapp (1970) suggested that the average Tcw is around 33°C. Cannon and Keatinge (1960) tested men immersed head-out, at rest in increasingly colder water until Tre fell steadily after 2.5 hours and found that metabolic rates increased in water lower than 33°C.

Most learn-to-swim instructional programs have a 30 -45 minute class time limit, so a 2-3 hour immersion study may not seem relevant to our discussion. The importance of the lengthy time lies in considering that instructors may be teaching back to back lessons without re-warming. Studies whose protocols involve shorter (60 minutes or less) durations will have more relevance in establishing guidelines for participants. Carlson et al. (1958) who found that men immersed to the neck for 60 minutes began shivering when water temperatures dropped 2-3°C below control (33°C). Craig and Dvorak (1966) studied men immersed head-out, at rest and found that when water temperatures were below 35°C for a duration of 60 minutes, Tre was lower than for control values. Strong et al. (1985) found that males immersed horizontally at rest in water at 35°C and 32°C for 1 hour at a time showed similar metabolic responses when compared to pre-immersion values. These studies support recommending water temperatures for inactive adults with wide variations in %BF and surface area to mass ratio who are immersed to the neck for an hour in the range of 28 - 35°C.

These temperatures represent a range for inactive, head-out adults but the true challenge of thermoregulation in the water is when the body is fully immersed (submersion) as in swimming, free diving, or SCUBA diving. Head submersion increases the cooling rate of the body (22, 51, 52). Pretorius et al. (2006) studied 8 male subjects in Tw at 17°C under four separate conditions; 1)head- out body insulated, 2)head-out, body not insulated, 3)head submerged, body insulated and 4)head submerged, body not insulated. They found that the head which accounts for only 7% of the surface area of the body contributed only 10% of the total body heat loss. Head submersion increased the cooling rate by an average of 42%. Giesbrecht et al. (2005) reported an increase in body cooling by as much as 40% with head submersion as compared to head-out immersion.

It would seem intuitive that for swimming, thermal comfort may require a higher range of temperatures. Previous studies have confirmed that a number of factors influence heat loss during immersion. The most significant of these are subcutaneous fat thickness, surface area to mass ratio and immersion at rest versus with exercise, with particular respect to exercise intensity. It is important to consider the influence of these factors before establishing guidelines for swimming programs.

The Role of Subcutaneous Fat and Surface Area to Mass Ratio. Numerous studies have demonstrated the role of subcutaneous fat thickness in managing cold stress. (3, 4, 7, 35, 42, 47, 54, 59) Body fat has a low thermal conductivity and therefore helps retain body heat (38). Individuals with low %BF cool more quickly than those with high %BF when immersed in cool / cold water. Cannon and Keatinge (1960) found that thin men had a steeper rise in MR (an indication of shivering) than fat men. Wade et al. (1979) reported on men immersed at rest lying on a cot in water at 25.2°C and found a significant correlation between heat flow from the head, neck and torso and subcutaneous fat thickness. Smith and Hanna (1975) determined that the range of Tcw (29 - 31°C) for 14 male subjects was a result of the differences in subcutaneous fat thickness.

Although subcutaneous fat provides significant insulation, body size, (surface area to mass ratio) has also been found to contribute to body heat loss (17, 38, 41, 49, 54, 62, 65). Beckman and Reeves (1966) showed that the rate of heat loss is a function of the amount of surface area exposed to the water and the relative thermal conductivity of that area. Strong et al. (1985) found that small individuals demonstrate a greater increase in tissue insulation and metabolic heat production per decrease in Tre and Tsk than large individuals. This holds true for the amount of surface area exposed to the water as well as the surface area to mass ratio of the extremities. Sagawa et al. (1988) reported that resting heat loss was greater in the limbs than the trunk. Lee et al. (1997) studied men immersed at knee, hip and shoulder levels and found that thermal balance in shoulder level water was not possible in water at 15 or 25°C.

The Role of Exercise. There is little doubt that at certain temperatures exercise contributes to thermoregulation (13, 26, 32, 36, 43, 44, 50, 57). When a person begins exercising in the water, heat from the working muscles helps maintain thermal balance. To what degree depends not only on the temperature of the water, but to a great degree on the type of exercise and the intensity of the effort (determine as a percentage of VO_{2max}). There is an inverse relationship between water temperature and the intensity of exercise needed to attain / maintain thermal balance. In general, the colder the water (to a point), the higher the intensity needed to maintain thermal equilibrium (13, 32, 43, 44, 58, 66, 67). There are also temperatures below which no amount of exercise can keep the core temperature from dropping (26, 27, 32, 41).

Exercise intensity can be expressed in a number of ways such as a percentage of VO_{2max}, in energy equivalents such as METs (metabolic equivalents), milliliters per kilogram per minute, liters per minute, kcal per kilogram per hour, and kcal per minutes. Each of these is based on a persons' body weight and therefore difficult to compare from study to study. For the purpose of this discussion we will identify each effort as light, moderate, and hard work to simplify comparison when possible.

With light exercise, the range of comfortable temperatures for head out immersion seems to vary between 26 and 32°C. Lee et al. (1997) found that light exercise (leg cycling at 35% VO_{2max}) did not maintain Tre in shoulder depth water at 25°C. Choi et al. (1996) studied subjects on a bicycle ergometry at MR corresponding with 60 kcal·h-1·m-2 (very light workload). For most subjects in this study, Tre declined in water below 30°C whether during rest or exercise. Craig and Dvorak

(1968) reported that during light (.70 l/min) leg work, Tre continued to decline when water was less than 32°C. Pirnay et al. (1997) reported that subjects in their study were able to maintain thermal balance with light and moderate exercise in 26°C. With moderate workloads, it seems that most adults can maintain thermal equilibrium at approximately 25°C for efforts of 30 to 60 minutes (32, 44, 58)

The type of exercise performed in the water is also a variable in thermoregulation. The types of exercises representative of the "head-out" immersion studies include arm exercise such as rowing, or arm cycle, ergometry (66, 67), leg exercise, the most common of which is a cycle ergometry (9, 13, 26, 32, 41, 44, 50, 65) and a combination of leg and arm exercise (28, 43, 49, 67). It seems that leg exercise results in a smaller fall of Tre with cold immersion or maintains thermal balance when compared to arm exercise at the same level of effort (26, 49, 66, 67).

Efficient swimming requires head submersion and a greater use of the arms. Wade and Veghte (1977) used radiograms to study heat loss areas in swimming subjects in 23°C water. The warmest areas recorded for the non immersion control were in the chest, groin, lower abdomen and neck. After a 500-yard freestyle swim, the warmest areas were the trapezius, deltoids, triceps, biceps brachii and the pectorals (i.e., the active swimming muscles). The legs, however, remained cooler. Considering that swimming is a predominantly upper body exercise, it would seem intuitive that temperature ranges for efficient swimming might be somewhat higher especially when compared to ranges for leg dominant, head-out, water exercise protocols.

In swimming (freestyle and breaststroke) research, the most common temperatures in literature are 18°C (30, 47, 64), 21°C (21, 31, 54, 56), 25°C (39, 54, 64, 74), 26°C (11, 30, 46, 47) and 33°C (20, 21, 31, 48, 56, 75). These temperatures have been studied to establish the range for competitive swimming and /or to identify a range of temperatures that affect swimming performance. As would be expected from previously reviewed immersion literature and with all things being equal (surface area to mass ratio, subcutaneous fat thickness and duration of immersion) temperature ranges for swimming are dependent on swimming intensity (30, 31, 47).

Fujishima et al. (2001) looked at thermoregulatory responses to prolonged (120 minutes) breaststroke in 23, 28 and 33°C. Subjects swam at 50% VO_{2max} in 23°C water, 43% VO_{2max} in 28°C water and at 42% VO_{2max} in 33°C. Tres declined in both 23 and 28°C and increased in 33°C water. Robinson and Somers (1971) looked at swimmers swimming freestyle for 60 minutes in water 21, 29 and 33°C. They reported that in 21°C the Tre of the slowest swimmers declined and the average Tre of the fastest swimmers increased slightly. They suggested that optimal water temperature for swimmers was nearer 29°C because at that temperature core and surface temperature gradients were adequate for heat conductance. The findings of Nadal et al. (1974) agree. They suggest that the optimal water temperature for sprint performance is between 28 and 30°C.

Houston et al. (1978) studied male subjects swimming breaststroke for an hour at 65% VO_{2max} in 21, 27, and 33°C. Core and esophageal temperatures tended to rise in 27°C and decreased by a similar magnitude in 21°C. They suggested that competitive swimmers might benefit from the thermal stress presented by 21°C but that recreational swimmers might need at least 27°C to maintain thermal equilibrium. Galbo et al. (1979) confirms these findings. Subjects in this study reported that it was more difficult to swim in 21 and 33°C as compared to 27°C water. In

Holmer and Bergh (1974) subjects swam breaststroke in three different water temperatures (18, 26 and 34°C) with two different intensities. They performed a 20 minute submaximal (approximately 50% VO_{2max}) effort for 20 minutes and then a maximal test in each water temperature. For all maximal efforts Tes rose exponentially. Tes was lower for both 18 and 26°C with submaximal effort for 20 minutes.

It would appear that water temperature for thermal comfort during light to moderate swimming intensities can range from 27 - 32°C. For maximal efforts that range can vary from 18 - 30°C. Keep in mind that these studies were done with adult subjects. These ranges will need to be adjusted based on age and possibly gender.

Sex and age. Adjustments to cold exposure have been found to differ with age and sex (10, 15, 18, 40, 43, 59, 61, 71, 72). Though reasons for this cannot totally be explained, it is clear that children and older adults chill faster than young and middle aged adults and males chill faster than females. Falk (1998) suggested that physical and physiological differences may explain some of the age-related adjustments to cold exposure. The two most significant physical differences are surface area to mass ratio and %BF. Children have a higher surface area to mass ratio than adults which increases heat loss. In many instances, young to middle aged adults have a higher % body fat. Both of these physical factors have been shown to increase the cooling rate of children over adults (59, 61, 71).

When comparing young adults (18-30) to older adults (50-72), physiology seems to play a greater role than the physical factors. Falk et al. (1994) compared young adults to trained and untrained seniors at Ta thermoneutral (22°C) and Ta 5°C for 30 minutes at rest and 30 minutes of exercise. Young adults were able to maintain Tre with low intensity exercise, trained and untrained seniors were not. Collins et al. (1985) found that older adults had a significantly greater increase in blood pressures at Ta 6°C than younger adults. LeBlanc et al. (1978) found a significant relationship between VO_{2max} and a fall in skin temperature. They found that subjects with lower VO_{2max} experienced a larger drop in Tsk. Maximal aerobic power decreases with age and a lower VO_{2max} could account for some of the age related differences in cold stress responses. Frank et al. (2000) supported this hypothesis.

The Upper Limits of Thermal Comfort. There are warm water temperature limits for thermal comfort as well. Veicsteinas et al. (1982) found that vasodilation (heat dissipation) occurred at water temperatures between 32 -33°C in men immersed head-out at rest for 3 hours. Craig and Dvorak (1966) reported that when water temperature was 36 or 37°C, men showed a continuous increase in the central temperature. Tre also increased with a high work load in 28 - 32°C water. Participants in this study reported feeling most comfortable in 34-36°C and feeling tired and restless at 37°C.

Shimizu et al. (1998) found that Tre rose significantly at 29°C with exercise at 50% VO_{2max}. Pirnay (1997) also found that sub-maximal levels of exercise (approximately 50% effort) caused hyperthermia in water ≥ 30°C. Costill's (1967) findings (20 minutes of submaximal swimming) suggest that if a person is immersed in water below 32°C he/she will become hypothermic at a rate proportional to the duration of immersion or the difference in the thermal gradient below 32°C.

It would seem appropriate than to have temperature ranges for aquatic instructional programs adjusted based on activity level and age of the participant. Younger children and older adults need warmer water for thermal comfort and balance. The lower the intensity of the effort, the higher will be the accepted ranges. Participants learning to swim (low intensity or limited activity) need warmer water than more proficient swimmers, participating at a higher level of intensity. The duration of the lesson will have to be based on the other parameters and also be related to current thoughts about learning theory.

Summary

In summary, the weight of the evidence suggests that for each person there is a water temperature range in which he/she is most comfortable at rest and at different levels of exercise intensity. The number of possible interactions (age, sex, subcutaneous fat thickness, surface area to mass ratio) makes it nearly impossible to set a specific standard for each person / activity in the water and, therefore, only general guidelines will be given.

Based on 9 LOE 2a studies, the recommended water temperature range for adults ages 17-55 years immersed with head out of water, at rest, in an indoor pool with controlled humidity and air temperatures for durations ranging from 40 – 120 minutes is 29 - 33°C (84.2 – 91.4F). Adults with either higher subcutaneous fat levels or surface area to mass ratio or both, will tolerate water at the lower end of the range for longer periods of time.

Based on 11 LOE 2a studies, the recommended water temperature range for adults ages 17-55 years in an indoor pool with controlled humidity and air temperatures for durations ranging from 20 – 120 minutes of swimming at low intensities is 29° - 32°C (84.2° – 89.6°F). Adults with either higher subcutaneous fat levels or surface area to mass ratio or both will tolerate water at the lower end of the range for longer periods of time.

Based on 11 LOE 2a studies, the recommended water temperature range for adults ages 17-55 years in an indoor pool with controlled humidity and air temperatures for durations ranging from 20 – 120 minutes and swimming at moderate (at least 50% effort) to high intensities is 26° - 28°C (78.8°- 82°F). Adults with either higher subcutaneous fat levels or surface area to mass ratio or both, will tolerate water at the lower end of the range for longer periods of time

Based on 11 LOE 2a studies, the recommended water temperature range for adults ages 17-55 years in an indoor pool with controlled humidity and air temperatures for durations ranging from 15 – 135 minutes head out exercise at low to moderate intensities is 26°-28°C (78.8°- 82°F). Adults with either higher subcutaneous fat levels or surface area to mass ratio or both, will tolerate water at the lower end of the range for longer periods of time

Based on 31 LOE 2a studies, the recommended maximum water temperature range for adults ages 17-55 years in an indoor pool with controlled humidity and air temperatures for durations ranging from 15 – 135 minutes at rest or with low intensity exercise is ≤ 32°C (89.6°F). Adults with either higher subcutaneous fat levels or surface area to mass ratio or both, may not tolerate water at 32°C (89.6°F) for long periods of time. Watch for signs of hyperthermia. (For moderate (at least 50% $V0_{2max}$) or higher intensities water temperature should not exceed 27°C (80.6°F)

Recommendations and Strength

Standards. None

Guidelines. Based on 31 LOE 2a, 4 LOE 2aE studies and 2 LOE 5 studies, in a controlled environment (defined as an indoor pool with controlled humidity and air temperature), and with most of the consideration given to the level of intensity of the activity (as the activity intensity increases thermal balance can be achieved at the lower end of the range) and the immersion time (as immersion time increases core temperature decreases)

Infant / preschool aquatics (20 to 30 minutes*)

Water temperature - water temperature should be ≥32° C (89.6º F)

Learn to swim up to ages 6-15 (30 to 45 minutes*)

Water temperature - water temperature should be ≥ 29° C (84.2º F)

Junior Lifeguard ages 11-14 (45 to 60 minutes*)

Water temperature water temperature should be ≥29° C (84.2º F)

Lifeguard training up to ages 15 –55 (60 to 120 minutes*)

Low intensity activity-water temperature should be 29° to 32°C (84.2° to 89.6 F)

Intense activity – water temperature should be 26° to 28° C (78.8° to 82° F)

Water Safety Instructor up to ages16-55 (60 – 120 minutes*)

Low intensity activity-water temperature should be 29° to 32°C (84.2 ° to 89.6°F)

Intense activity – water temperature should be 26° to 28°C (78.8° to 82° F)

* Student immersion time per session.

Options. Instructors should watch for signs of hypothermia or hyperthermia as an indication that it is time to end the session. For water temperatures below the recommended ranges the following options are suggested:

1. Add clothing that does not compromise safety (5 LOE 2a studies).
2. Covering the head that does not compromise safety (3 LOE 2a studies).
3. Limit the amount of time in the water.

DOI: https://doi.org/10.25035/ijare.07.02.09