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INTERVAL TRAINING, HIGH-INTENSITY INTERVAL-TRAINING, AND USRPT

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Introduction

Ultra-short race-pace training (USRPT) has received considerable attention since the term was first published in 2011 (Rushall, 2013a). Despite the intention of writing as many explanatory articles as possible about the training format (http://coachsci.sdsu.edu/swim/usrpt/table.htm), with the hope that misunderstandings and a lack of understanding would not exist in swimming coaches and other interested individuals, much criticism has been steeped in those characteristics that were intended to be avoided (e.g., Beliaev, 2015; McGinnis, 2015; Leonard quoted by Muchnick, 2014). In the words of the physicist Wolfgang Pauli, those writings and statements *"do not even rise to the level of being wrong"* (Lemonick, 2006).

The purpose of this paper is to clarify and record features of USRPT that have been ignored/unknown by writers mostly in swimming-related publications. It involves several diverse events and concepts in the history of exercise science, particularly in the domain of exercise physiology. Without developing into a tedium of facts and minutiae, this writer has chosen events and concepts that develop a general picture of significant occurrences relating to USRPT and its historical evolution. By doing that, it is hoped that the false information and premises that have been so shamelessly expressed in the past and probably in the future will be corrected or at least ignored.

Original Interval Training

Woldemar Gerschler, a German track coach, originated the concept of *"interval training"* in the mid- to late-1930's to accommodate the training of elite track athletes. He was associated with cardiologist Dr. Herbert Reindel. Frequently, Gerschler credited Reindel with the ideas and science that he employed in his coaching. It was thought that alternating work and rest intervals was a better way of developing cardiorespiratory endurance, particularly the heart, than continuous running with faster bursts of efforts (*"Fartlek"* training) or long steady-distance work such as that touted by Arthur Lydiard in New Zealand.

The training effect of interval work occurred during the rest, not the exercise. The duration of the rest was governed by an individual's heart rate. The effort level in the running-work approached the maximum heart rate (~180 bpm; HR_{max}). Rest continued until the heart rate declined to ~120 bpm, whereupon the next work bout again elevated the heart rate to its presumed maximum. This structure was guided by an athlete's physiology, not a convenient clock. It was truly individualized for work rates that were particularly intense (thus, interval training originally used a very high level of exertion). However, the work and rest intervals were formulated, the training outcome was preferable to that which could be achieved in continuous or less intense intermittent exercise bouts.

Gerschler (1963) recounted the three reasons why interval training should be preferred: i) It takes less time than other training forms; ii) it imposes a more precise powerful stimulus through *"Local Muscle Endurance"* (movement specificity); and iii) it requires an exact control of the intensity of the training stimulus and of the effort duration. The most difficult aspect of interval training that heightened the challenge for Gerschler to convince other coaches to use it was that work over only 100 m or 200 m was sufficient for much longer races (*Racing Past*, no date). That is still a problem with today's presentation of *Ultra-short Race-pace Training* (Rushall, 2013a, 2014a).

With each individual reacting to his/her own recovery rates between work-bouts, Gerschler's formulations for effective training did not facilitate the training of groups. The frequent observations some years later in swimming programs of all athletes doing the same work at the same time with the same rest periods were not instances of interval training. Unsubstantiated alterations in the successful Gerschler-Reindell model began to emerge without any consideration of what might happen because of the changes[1]. Within those changes was a naïve assumption that if the coach intended to do well by his group of athletes then good would be done. With the advent of exact times for all athletes, that is fixed-duration work and rest intervals, which facilitated the organization of large squads of swimmers, individualization was lost and some athletes would not benefit the same way when all trained with the same fixed-parameters. That was how much of the western swimming world initially attempted to adapt interval training.

In the laboratories, particularly those in Sweden in the 1950s (Astrand et al., 1960a, 1960b, Astrand & Rodahl, 1977; Christensen, Hedman, & Saltin, 1960; Christensen, 1962), work rates were fixed so that variations in work and rest durations could be compared which resulted in further understanding of training effects (see Figure 1). At defined work rates, close to what now would be termed HR_{max} or VO_{2max} (variously maximal oxygen consumption, maximal oxygen uptake, peak oxygen uptake, or maximal aerobic capacity), the following were demonstrated.

1) Long work and rest intervals (e.g., four minutes of work and four minutes of rest) developed fatigue (lactate accrual and glycogen depletion) more than when work and rest intervals were shorter (e.g., one minute of work and one minute of rest). Fatigue in the shorter intervals developed but often to an elevated steady-state or eventual termination of the work over a longer period of time.

[1] When a successful formula for a particular outcome exists, it is imperative that the formula be followed to achieve that outcome. If the formula is altered without fact-based reasons, the outcome declines from the original. Thus, Gerschler's interval training required certain events to produce successful athletic performances. The effects of swimming activities worsened/lessened when swimming coaches continually altered interval training. A good example is a descending set. With each repetition providing a different physical stimulus to that which preceded it, the body/brain learns nothing other than to cope with single exposures to stressful stimuli. There is no improvement in performance since the requirement for repetition to promote learning and adaptation is not met in the descending set. Similar swimming sets with varied stimuli, such as broken swims (the stimulus duration is altered), ascending sets, overdistance tasks, simulators, etc. train a swimmer for no specific event but rather develop a general coping capacity that is not particularly efficient. It is no wonder that traditionally trained senior swimmers do not improve in performance from year to year but rather their performance declines despite *"variety"* being introduced based on the hope that improved outcomes will result.

2) Very short work and rest intervals at a high work-intensity (e.g., 20 seconds of work and 20 seconds of rest) could be endured for long periods of time without the physiological fatigue phenomena of lactate build-up and glycogen depletion.

3) The duration of the very short work and rest intervals was determined by the work intensity. The more strain involved in the work, the shorter the duration of the work and rest intervals.

4) Short work and rest intervals were the avenue for achieving the greatest amount of work over an extensive period and allowed opportunities (i.e., trials) for specific work adaptations over the shortest calendar duration of any of the differing work and rest formulations.

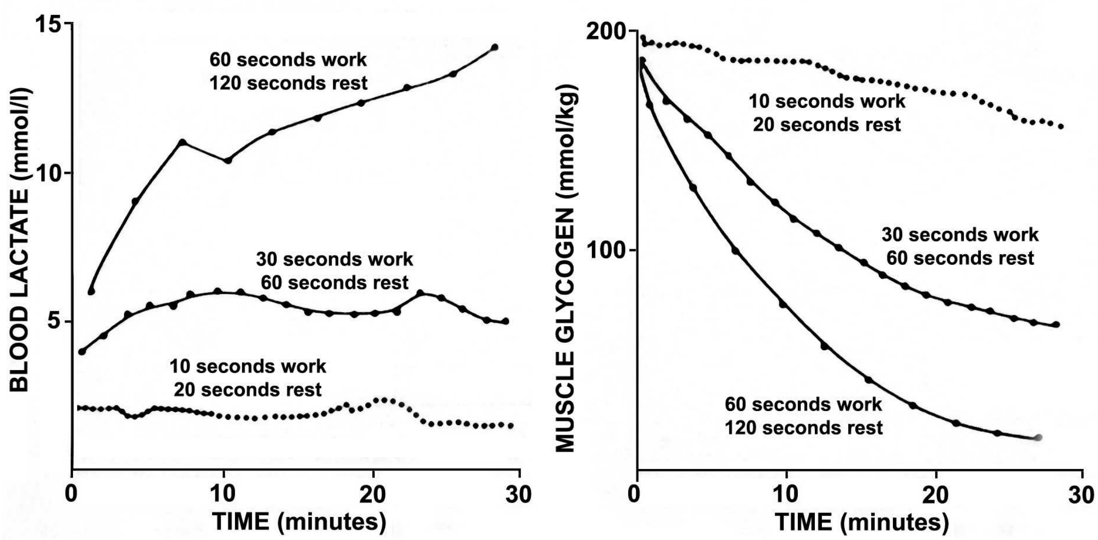

Figure 1. Constant rate exercise and blood lactate (left) and muscle glycogen (right) during interval training (after Astrand & Rodahl, 1977). The total work output and the ratio of exercise to rest was the same but the duration of exercise was 10, 30, and 60 seconds. Short work and rest intervals tolerated the exercise demand very well. Longer work and rest intervals increasingly made the work more difficult such that after 30 minutes total duration the 60 seconds of work and 120 seconds of rest led to close to complete fatigue. Research results such as these are the basis for advocating short work and rest interval formats as *ultra-short training* (Rushall, circa 1967) and its incorporation into USRPT.

Christensen (1962), in a review of short work and rest research, presented the work of Astrand et al. (1960b) (see Figure 2 to the right). It showed that the absolute amount of work completed in intermittent work and rest formulations was always greatest for the short work and rest period paradigm when compared to longer intervals and even when the level of work was reduced by extending the work to rest ratio or by lowering the work level. A detailed explanation of what facilitates the non-accumulation of lactate and maintenance of glycogen stores was summarized by Rushall, (2013b).

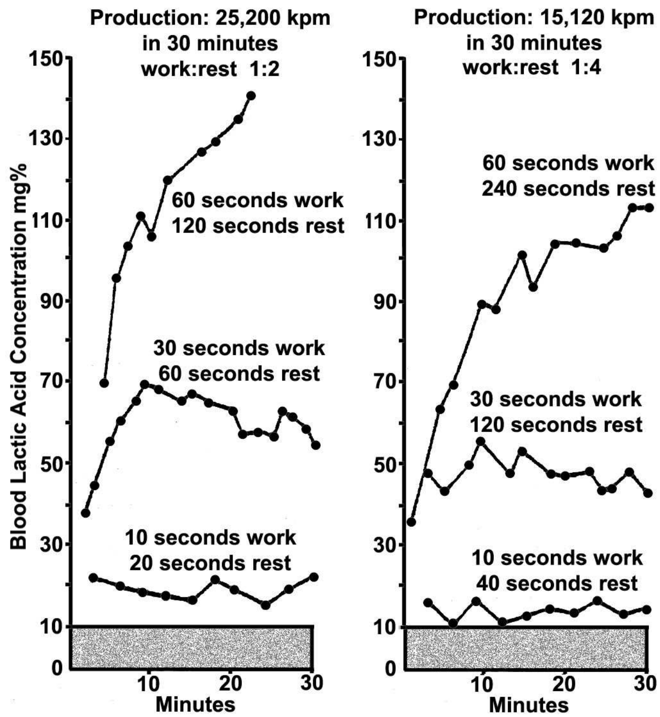

Figure 2. Blood lactate concentrations in two constant work-rate tasks with the same work to rest ratios for different durations.

A further partial explanation for the benefits of short-work periods was discovered long ago by the Italian physiologist Rodolfo Margaria and associates (Margaria, Edwards, and Dill, 1933). They showed no extra lactic acid appears in the blood after exercise involving an oxygen debt of less than 2.5 liters. When exercise requires a larger amount of oxygen, lactic acid accumulates at the rate of 7 g for each liter of additional oxygen debt. Consequently, that explains why lactic acid does not accumulate in the shortest work periods involved in the Swedish studies. Occasionally, the oxygen debt of a short repetition slightly exceeds 2.5 liters, which accounts for the very slight fluctuations in lactate concentrations (see the two figures above) throughout the repeated exercise. In practical terms, lactate is not problematical in short work because it does not accrue during a full set of repetitions. The brevity of the work periods and the limited demands for oxygen debts in the region of 2.5 liters or less prevent lactate accumulation.

In Australia in the 1940s and early 1950s, Professor Frank Cotton of Sydney University experimented further with interval training. Consistent work and rest durations were formulated but the work levels during the work interval were left to each individual. The work of Canada's Hans Selye, particularly his *General Adaptation Syndrome* (*GAS*), influenced Cotton's formulations and in particular, his devoted colleague the Hall-of-Fame swimming coach Forbes Carlile[2]. Selye recognized that over a calendar period athletes could sustain work levels but eventually would fail and would require a relatively long time to recover performance and physiological capacities. Thus, in Cotton's formulation training would continue in the traditional fashion but the work level of each training session would be determined by an athlete's physiological, and possibly psychological, state at that time. It was asserted that if athletes (e.g.,

[2] The magnitude of influence of Forbes Carlile and later with his wife Ursula, on the science of swimming coaching and swimmer performances cannot be measured. While Cotton worked with various sports, at the same time Carlile focused on swimming and provided the window into that sport from which Cotton's ideas were initially viewed.

swimmers) varied the work intensities according to their individual needs with each interval training session that the occurrence of the final stage of the *GAS*, *"The Stage of Exhaustion"*, could be avoided or at least inhibited allowing longer calendar periods of work. An example of such work in a swimming pool would be *"a mile of 55s on 50 seconds"*. Roughly, that worked out to be something like < 35.0 seconds of work with ~15.0 seconds of rest. The work rates of swimmers at that time would be suited more to distance swimming than 200 m or less racing distances. Coaches who favored harder work, persisted with a similar structure but increased the intensity of the interval-work performances which then were more conducive to shorter swimming-race distances. During the 1950s and early 1960s, Australian swimmers were prominent in all Olympic crawl-stroke distances as well as in the form strokes.

In a dual 55-yard pool facility at Ryde, a suburb of Sydney Australia, the Forbes Carlile School of Swimming enjoyed a level of popularity that led to overcrowding on some occasions. Normally two 55-yard training pools were available for use, but for the last hour of each day only the T-shaped training pool was usable and had to accommodate senior and age-group swimmers. Very short work and rest interval training was necessitated by the swimmer-density and pool-space restrictions. Ursula Carlile would have her age-group swimmers, perhaps as many as 60, swim across the narrower section of the pool (six lanes wide). The longer *"top of the T"* was 25 m wide and Forbes Carlile would have his swimmers (usually between 30 and 40) swim single widths. Swimmers would do this in waves of like performance, often organized so that when the last swimmer of the last wave touched the first wave would set-off again. Being competitive, many swimmers would race each other for width after width, which elevated the effort levels of the swimming. The *"width-swimming"* appeared to approximate the short work and rest interval high-effort levels of swimming defined by the Swedish physiologists referred to above. From the results of the Ryde senior and age-group swimmers during the 1960s, it facilitated the development of fast swimmers in all strokes.

The outcome of the mix of *"distance-training"* and *"sprint-training"* was that Ryde swimmers were very prominent in all distances and strokes in Australian swimming. An example of both forms of training affecting a swimmer was Jan Murphy, who as a 16 year-old swam for Australia in the 4 x 100 m relay and the 400 IM at the Tokyo Olympic Games. At those Games, Russell Phegan represented in the distance freestyle events, Gillian de Greenlaw (the youngest team member at just 13 years) in the butterfly, and Marguerithe Ruygrok in the breaststroke. Often the diversity of strokes and distances of those Ryde representatives was used to justify the types of training used and its adaptability to all swimmers' needs (strokes and distances). This trend of diverse training effects persisted for the rest of the duration of the Carlile's tenure at the Ryde facility. Despite a change in facility at the end of the 1960s, the Carlile successes continued.

The point behind this description and diversion down *"memory-lane"* (or a parochial view as one might call it) is that interval training was first developed for intense work and sided with being short work and rest intervals rather than durations in excess of one or two minutes. Interval training produced faster and greater training effects than continuous work. Continuous or long-work long-rest training could not match the volume of intense work that was possible under the short-duration work and rest formula. By the start of the 1960s, research verified that short work and rest interval formats facilitated very high levels of effort (greater than the levels required to reach VO_{2max} or HR_{max}), were more productive in terms of total work output, and allowed the repetition of specialized training experiences that mirrored those required for competitive performances.

In the mid-1960s *interval training* was synonymous with *short-work short-rest high-intensity training* (later termed *ultra-short training*). *Ultra-short training* was the avenue for achieving the greatest volume of very high intensity swimming.

Since the 1970s

For some reason, one of which could be the lack of adequate up-to-date scientific education, swimming coaches, as well as those in other sports, began to invent variations of interval training under names such as ascending and descending sets, broken sets, repetition training, etc. The blind advocacy that good things were happening to swimmers when experiencing inconsistent fatiguing stimuli went unquestioned for a number of decades. Cousilman (1968, pp. 212-233) catalogued the variations of training and explained the hypothetical value of each. Writing as an authority, many coaches adhered to the theory and structures in the time-honored invalid reasoning procedure of *appealing to authority*. In time, the reason behind the training variations were shown to be invalid by substantive research that was ultimately revealed through brain research, particularly through the use of functional MRIs and PET scans (Ehrsson, 2001; Levy et al., 1999; MacIver et al., 2008). As well, Counsilman's explanations[3] provided hypotheses for research which in turn revealed verified understandings of how the holistic human body responded to exercise stimuli. While the original interval training was being distorted seemingly to the point where any intermittent exercise was labeled a variant of interval training, the defined parameters of the original interval training still persisted (Gerschler, 1963). The development of dogma in swimming training mainly arose from swimming coaching publications rather than physiology texts (Stager, 1999). US Swimming in 1993-4 developed a *"system"* of training that was based purely on the whimsy of a few individuals in Colorado Springs. Despite receiving lengthy feedback about the lack of validity and the errors contained in the documentation of the proposed system (e.g., Rushall, B. S., November 1, 1994; *An Evaluation of the Intended Energy Systems and Training Design Handbook*), it was published (US Swimming, 1994, *Energy Systems and Training Design Handbook*). It is a classic example of belief-based coaching. The lack of validity for the system is noteworthy. The scientific justification or basis for the design parameters did not exist in the real world. Swimming physiology and conditioning seemed to develop a life of their own irrespective of what *bona fide* research was discovering. Much swimming dogma remains to this day (e.g., Leonard quoted by Muchnick, 2014).

Counsilman (1968) considered swimming velocities that mirrored race-pace. It occurred in two forms of training, both of which broke from the classic implication of the term *interval training*. His *fast interval training* lengthened the rest intervals arbitrarily and assumedly so that recovery would occur and facilitate the next repetition being at race-pace. The duration of a recovery was guessed at for all swimmers in a squad as opposed to Gerschler's original formulation of waiting for the heart rate to recover to ~120 bpm in each individual. Recovery from sets of the *fast interval training* nature was long because fatigue was high from the experience. It was unwise to attempt daily exposures to that training stimulus. The training responses within a group were varied with some individuals working too hard, others just right, and still others not hard enough. That variation was demonstrated years later by Howat and Robson (1992) when they showed when a group of swimmers all experienced the same work criterion (in their case heart-rate range designated as the stimulus for aerobic training), only one in three age-group or senior swimmers were stimulated aerobically.

[3] Few will appreciate the value of Counsilman's explanatory attempts because they did stimulate meaningful research which unfortunately was rarely read by swimming coaches and authors of swimming coaching materials.

Counsilman's second form of near race-pace training was repetition training. It consisted of *"swimming a series of repeats of a shorter distance than and at a greater speed than that swum in a race"* (p. 215). In this work, the complete recovery of the heart and respiratory rate during the rest interval dictated when the next repetition would be attempted. In this format, the volume of fast swimming was quite low, the fatigue high, and the amount of recovery time extensive/excessive.

This writer recalls that Doc Counsilman used both fast interval training and repetition training mostly close to or during taper for big meets. The rest of the time, lower intensity swimming over greater distances (200 y/m was the favored distance) with shorter rests (*slow interval training*) was preferred. When freshmen were ineligible for NCAA competitions, their program was mainly aimed at having them develop a greater capacity and tolerance for larger work volumes than those they experienced in high school or age-group clubs prior to attending Indiana University.

From the early 1970s on, there gradually developed myths about training that were not supported by research. One was that the energy systems could be stimulated maximally or at least to a considerable degree separately by different types of work (Madsen, 1983; Sharp, 1993). That gave rise to the emphasis on aerobic training as being the stock-in-trade for swimming coaches and later to more exhausting work supposedly to train lactate tolerance. As well, the advent in the 1970s of wearable heart rate monitors set physiologists (often sponsored by commercial enterprises manufacturing the monitors) to describing heart-rate ranges where various effort levels caused different types of energy-system adaptations. The inventiveness of swimming coaches for devising categories of work spanned colors, numbers, verbal descriptions, and symbols. Physiologists joined the training system bandwagon and wrote papers with selected references to infer that aerobic *"base"* and training was important to achieve the best levels of swimming performance. However, when all is considered, the systems of training varied and developed unchecked even to this day, primarily because of books, *"scientific"* articles, and coaching organization education systems (i.e., the perpetuation of training myths). The reasons used to justify why a training form was adopted never to change again for the rest of a coach's involvement in the sport were overwhelmingly dogmatic. It is remarkable that coaching organizations still give the podium to those who espouse dogma that is unreliable, mostly invalid, and unsupported by facts. During this time and up to this day, despite the focus of coaching being on physiological training/conditioning, research began to show that the physiology of training was unreliable and irrelevant before attending to other performance-determining factors (Noakes, 1997; 2000, 2012; Rushall, 2009).

Professosr Rick Sharp (personal communication to Forbes Carlile, August 30, 1994) drew attention to the inadequacy of physiological training/conditioning in swimming:

> It seems that an appropriate effort for your sport scientists [Australian] and for ours would be to test the reliability and validity of this and other similar training concepts. *"Testing for testing sake"* is a problem that, in my opinion, has also been a major problem with our approach in Colorado Springs. But simple studies like evaluating the validity of *"critical maximum velocity"* would be useful. Simply testing athletes whenever they're available is fine if the research has already been done to determine: 1) The relative importance of physiological and biomechanical capacities in performance of our sport [swimming], and 2) the validity and reliability of the tests that are purported to measure these capacities. Unfortunately, these necessary steps are too often overlooked.

None of the developments in physical conditioning or training of swimmers followed the original concept of interval training. Respect for and adherence to the original boundaries of interval training ceased to exist[4]. A vast number of training sets and experiences developed, along with other very questionable pursuits such as drills, swimming with equipment, and land-training established themselves in swimming folklore as if they were relevant and effective activities for competitive swimmers. The changes written about were mainly uneducated guesses at what might work with swimmers. Major sources of those training misdirections were head coaches or the coaches of successful individual swimmers from seemingly across the world. Physiologists (a.k.a. *sport scientists*) also tethered themselves to successful swimmers and programs and espoused much questionable content (e.g., Rushall & King, 1994). The period covering 1970 to this day is not one about which swimming can be proud of its acceptance of its *science*.

Meanwhile, in the Fitness Industry

In a short historical review of the form presented here, there are likely to be omissions that some would say should have been included, there are likely to be opinions expressed with which others would disagree, and the extent of available evidence might not be completely inclusive. Having been in the physiology of work (particularly sports) since 1958, has given this writer experiences and associations that few could match in terms of their centrality to the whole area of training theory. Given that admission, other parts of the picture being painted here need to be discussed.

In North America in the 1970s, the fitness industry was developing virtually unchecked by governments and professional organizations. Initially, it did not seem to be all that popular or successful but by the mid-1980s the popularity of working out in a specialized facility with a plethora of machines designed to do wonders for a user's health started to take hold. The *"gym"* facilities and the equipment were multibillion dollar industries by the early 1990s and have remained popular. There was a realization that the need to exercise for health and personal image was important. The types of work tended to be continuous *"stair-climbing"*, stationary cycling, etc. in the fitness establishments.

At the same time, those who did not enjoy working out in mechanical jungles opted for group classes in all manner of movement-range activities (e.g., pilates, yoga, Zumba, etc.). The personal-trainer industry exploded as employment opportunities for individuals with none to some appropriate training. The point behind this class of exercise opportunities is that interval work was pushed into the background and replaced by extended periods of continuous work.

The third major and final influences on fitness were from institutional and governmental authorities. A great focus was on the amount of continuous activity to be performed each day to maintain baseline health. Whether it was 30 minutes of continuous running, 45 minutes of brisk walking, cycling, hiking, or more than 10,000 steps, the structure of the activities was particularly loose in dictating the intensity, activity, duration, and purpose of the exercise. There were a number of decades when working out, without accounting for the specific format or effects, was considered to be useful. It seemed that the major outcome was mainly one of having participants feel good in themselves and about what they were doing. To this day, store-front fitness establishments, complete fitness facilities, and instructional fitness programs (e.g.,

[4] When a successful formula for producing an effect is altered without factual support for the change, the original effect is reduced. Thus, the relevance of Gerschler's interval training was lessened by every *"innovation"* to the eventual point that modern traditional training (i.e., not USRPT) is largely irrelevant for improving swim performances (Noakes, 2012; Havriluk, 2013; Rushall, 2009).

YMCAs, Adult-education programs, etc.) offer the public many choices that yield a wide range of product outcomes.

The fitness industry was growing without much input from academic institutions or relevant scientists. The question that began to be asked in the mid-1990s (plus or minus five years), was *"is there a better way of getting fit that might take less time and resources."* Comparisons between continuous popular activities and broken structured exercise programs (i.e., a great variety of intermittent training formats) began to emerge in exercise science labs and from mostly masters degree students. A common format was to compare the effects of the traditional moderate to light load workout with newer presentations of higher levels of work. In time, possibly as recently as the mid 1990s, *high-intensity interval-training* (*HIIT*) was the label used for increased work intensities in blocks of alternating work and rest. HIIT is very common in movement studies and exercise science theses and dissertations these days.

One manner of implementing HIIT in swimming was to have every task swum as fast as possible. The tasks, often mixed to avoid boredom, led to little improvement in swimmers. The lack of specific-event training led to less than optimal performances despite the emphasis on very-fast (high-intensity) swimming. That use of that one form of HIIT only reinforced the adage that *mixed training produces mixed results*.

The choice of the label high-intensity interval-training when filled out actually means high-intensity high-intensity training. Original interval training implied high-intensity and the redundancy was completely unnecessary. HIIT is treated as if it is a new phenomenon. However, studies reporting the comparison of HIIT training to a traditional form of training (usually the *control group*) have employed a wide variety of work and rest durations that are not in accord with the classic definition of interval training. The one feature common to HIIT research is that the experimental manipulation is of an exercise intensity that exceeds the intensity of the control group. The manipulation is hypothesized to show that less HIIT work matches the training effects of the greater amount of control group exercise or that HIIT work produces effects that are much better than demonstrated by a control group. On many occasions, the HIIT approach showed that the physiologists and students involved did not have a satisfactory appreciation for the history of their subject matter. Showing that alternating work and rest exercises permit an individual to work at a higher intensity for a longer period was nothing new, it being the original realization of one of the values of interval training in the late 1930s by Gerschler and Reindell.

One of the positives from HIIT research has been the use of technologies that were not available yesteryear. More intense short-work short-rest formats of exercise achieved effects faster than long-duration work and rest periods and continuous exercises. As well, the measurements of factors such as aerobic adaptation (Cregg et al., 2013; Xu, 2013), muscle hypertrophy (Losey et al., 2013), young participant enjoyment (Martinez et al., 2013), and many more factors have been shown to develop in a superior manner under HIIT (Rushall, 2014b).

Some individuals who have criticized USRPT have claimed it is nothing new and has been used since the virtual outset of interval training (Muchnick, 2014 quoting John Leoanrd, Executive Director of the American Swimming Coaches Association). Other critics have claimed it to be an example of HIIT despite the physiology of its basis having been established in the late 1950s, well before the misinformed inventors of the HIIT label might have been born. Such claims associating USRPT with HIIT are ignorant of the facts behind USRPT and to a large degree, the development of interval training. They seem to enjoy making a public spectacle of how little they know about USRPT, the focus of their criticism.

If a physiologist or self-claimed expert states USRPT is a special case of HIIT training, the reader should understand the falseness of such a statement. The structure of ultra-short training was demonstrated in the late 1950s (see Figures 1 and 2) and to this day there has been no research study presented to refute the validity and reliability of it being a valuable and effective training method for very high-intensity/high-exertional work.

It is a sad commentary that in the Academy there are poorly informed individuals who are unacquainted with the development of major facets of work/exercise physiology and invent spurious procedures and inappropriate labels as if they were new discoveries.[5]

The status of training at the turn of the millennium was as follows.

1. Interval training was developed for high-performing track athletes and had exact parameters of short work and rest lengths, and work intensity (equal to or greater than VO_{2max} or HR_{max}), The ratio of work to rest was determined by heart rates. The results of this form of training were relatively predictable.
2. Over time, the nature of interval training was changed by many users without a factual base to justify the changes. With each change, the predictable training effects inherent in interval training lessened. In this writer's opinion, modern swimming training no longer contains influential elements of interval training but has a much greater irrelevant than relevant component in its make up. It is possible for swimmers to partake of eight months of *"hard"* training and not improve in important performance factors (e.g., arm power) and/or swimming times (Havriluk, 2013). The phenomenon of *"national team members"* in the USA not improving performances over the spans of quite a number of years shows that whatever the training they are doing, it does not provide an avenue for any relevant experience that would contribute to improved *"propelling efficiency"*.
3. The fitness industry promoted the term high-intensity interval-training (HIIT). The definition of HIIT is elusive. Work forms, intensities, durations, and calendar periods of involvement vary to such a great degree, that it is not possible to use any structure component or variable level as defining elements of the *"training method"*. In practical terms, it is often after the work has been done that the label has been attached. It seems that two features exist for HIIT to be declared. First, the work should be more intense than normal, and secondly, the format of the training should be intermittent (work and rests are repeated). Forms of training varied greatly and often included work bouts as long as four minutes (e.g., Losey et al., 2013). Many research reports given at conferences (e.g., American College of Sports Medicine) described the treatment as HIIT without any description of work or rest durations, only the exercise intensity. The lack of defining boundaries of what constitutes HIIT makes it invalid to describe a true interval

[5] One of the main reasons exercise physiology is uninformed about the history of its focus of study is that many journals associated with the subject have been digitized, but often only as far back as 1970. Much good work in physiology was produced in the 60 years prior to that year. It is almost an acceptable norm for the discipline to perform literature reviews through digitized services and to only report on what was digitally available. The pre-1970 productivity of work/exercise physiologists remains mostly untouched in the stacks of very established libraries. A competent review of literature should include an historical perspective often noting when new discoveries made old understandings obsolete, when new discoveries expanded the nature of understanding of existing topics, and the old discoveries that are still as relevant today as they were when discovered many years ago. In this writer's opinion, interval training as originally defined by Gerschler, is as relevant today for improving performances in a host of sports (e.g., rowing, swimming, kayaking, rugby football, Australian Rules Football – all sports with which this writer is familiar) as it was for improving track runners in the period covering the late-1930s to early-1960s.

model (see USRPT later in this treatment) as a form of HIIT. The vagueness brought into a conversation when such an association is proffered, adds nothing to understanding of the activity in question. It is as meaningful as a statement such as *"an American is an instance of Homo Sapiens"*. To refer to homo sapiens provides less information than contained in the term *"American"*.

4. The productive training of athletes requires attention to factors other than conditioning. Noakes (1986), in his description of *Laws of Training* (pp. 135-134) stated:

> The 'holism' of training encompasses two ideas. First that training itself must be balanced and varied, second, that what happens in the hours that we are not running also has a major influence on how we run. (p. 143)

The extent of holism in swimmer development extends much further than basically a physiological approach to conditioning athletes. This is expanded below in the next section. For want of a better explanation, the performances of serious swimmers should be built upon the development of technique, through a coach's excellent instruction of technique, the psychological factors surrounding training and mostly competitive tasks in competition settings, and the maximized conditioning of swimmers to their inherited limits.

HOLISTIC ULTRA-SHORT RACE-PACE TRAINING (USRPT)

USRPT is a system of integrated sport-science disciplines. A full explanation of its characteristics was provided by Rushall (2014a). Its genesis was described by Dr. Daniel Thompson III (2014).

> In the early 1960s, Swedish scientists published research on the benefit of short-work, short-rest repetitions (e.g., http://coachsci.sdsu.edu/csa/vol71/astrand.htm). The pace was full-bore, without the specificity of USRPT. Rushall used this form of interval training with great success in high-school rowing, and Forbes and Ursula Carlile used it effectively in swimming at that time. To label it, Rushall coined the term *"ultra-short"* in his 1967 Honors MSc thesis at Indiana University. He first published the term in an article in 1970 (Rushall, 1970). The article was reprinted in *Amateur Athlete* (May, 1970); *Swimming World* (May, 1970); and *International Swimmer* (June, 1970).]
>
> In the ensuing 45 years however, swimming came to be dominated by aerobic and lactate tolerance training, and the only mention of ultra-short was by Rushall, in publications such as Rushall and Pyke (1991). Nonetheless, rowers, kayakers, and track athletes used ultra-short training to great advantage, as did some teams in various codes of football (Australian Rules, Rugby Union, Rugby League). In 1996, Rushall used it to train two girls in Kayak who dominated the 1996 US Olympic Trials. That followed similar work with Cathy Marino who under difficult circumstances qualified several times to represent the USA at World Championships and Olympic Games.
>
> Some coaches were experimenting with short-work, short-rest training sets with considerable repetitions during that time (e.g., Beckett, 1986; Mujika et al., 1996; Termin & Pendergast, 2000). However, the dogmatically couched and fantastically developed traditional training model, the focus of many swimming coach education schemes, was gaining much following.
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> In 1990, a significant study by Toussaint et al. (1990) on velocity-specific techniques attracted Rushall’s interest [despite the same implication being published by Craig and Pendergast in 1979]. At the time, however, Rushall was preoccupied. He coached rowing, commuted to Australia as Director of Coaching for NSW Swimming, and busied himself with dispelling the myths of lift theory and Bernoulli's Principle as being key mechanisms of propulsion in swimming (Rushall et al., 1994).
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> But then, in the 1990s and early 2000s Belgian, Dutch, and Portuguese scientists produced further exciting research on the interdependence of technique, velocity, and energy supply. This grabbed

Rushall's full attention, and he embarked on a deeper exploration of its implications for swimming, as related to the *Principle of Specificity*. He found no research to support the belief that traditional training (and its adjuncts, such as land-training) consistently benefited performance. Ultimately, in 2011, USRPT conditioning came together as a mature concept, formally presented as the first edition of *Swimming energy training in the 21st century: The justification for radical changes* (see second edition - Rushall, January 2013a).

At that time a groundswell of broad-minded coaches and swimmers took notice and brazenly put USRPT to the test. Early implementers included one of the leading age-group clubs in Australia, Cherrybrook Carlile. Cherrybrook's Head Coach, Greg McWhirter, compared ultra-short race-pace training to traditional *"slow"* training, as advocated in swimming LTADs (Rushall, 2010). His investigation was for partial fulfillment of the requirements for Gold Certification in the Australian Coaching Education Scheme. Age-group swimmers overwhelmingly opted for ultra-short race-pace work for training and technique work. The findings of McWhirter's study pushed Brent Rushall to introduce USRPT. At almost the same time Coach Brendon Bray, then with San Diego State University Women's Swimming program[6], studied and implemented the ultra-short race-pace training format from early 2009. A grass-roots phenomenon was born with the publication of the "*Energy training*" paper in 2011. Rushall responded by adopting his current role as mentor to the movement -- with occasional seminars, consultations, and, as feedback streamed in, explanatory articles in the *Swimming Science Bulletin*. He says, *"To this date, I have not had one suggestion where I might be wrong in the interpretation of the research involving humans and sporting endeavors"* [with regard to USRPT].

The chronology above shows that short-work short-rest interval training has been known to be the most effective form of training no matter what the intensity of the training stimulus as long as it is in the *"challenging"* range. To set up swimming sets of 8 x 400 FS on 7 minutes is crazy when better swimming quality and higher performance levels could be accommodated by sets such as 30 x 100 holding 1:00 per repetition on 1:25. Those 100s would be much more meaningful, relevant, and valuable to the 1,500 m swimmer. One can conclude that any program that has sets such as 8 x 400, or 16 x 200, 2 x 2000, etc. is not providing an optimal training experience for a swimmer, no matter what event is of particular interest.

The labeling of short-work short-rest sets as *"ultra-short"* training occurred years before the relatively meaningless label HIIT came into vogue. Ultra-short training is not an instance of HIIT but some variants of HIIT could be called ultra-short work. Indeed, some HIIT research was used to justify the structuring of USRPT. The distinction is important because any failure to recognize the chronology of the ultra-short and HIIT labels and asserting commonality between the two is but a display of ignorance by the user/writer in question.

The advent of USRPT brought into focus areas of sport/swimming science that seem to have been disregarded. A major purpose of swimming science has been to determine what factors differentiate levels of performer. The overwhelming focus has been on physiological and conditioning factors. However, the implication from a number of studies associated with biomechanics has reinforced the notion that technique is the most influential factor in determining swimming success (Cappaert et al, 1996; Cappaert, Pease, & Troup, 1996; Chatard et al., 1990; D'Acquisto et al., 2004; Dutto & Cappaert, 1994; Havriluk, 2010; Kame, Pendergast, & Termin, 1990; Stewart & Takaqi, 1998). Technique discriminates between winners and non-qualifiers in Olympic competitions (Cappaert & Rushall, 1994). Technique should be emphasized more than any other aspect of swimming science. The movement efficiency of a swimmer leads to the concept of propelling efficiency which is one of the few indexes that

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[6] Now Head Coach of Women's Swimming and Diving at the University of North Texas, Denton, Texas.

discriminates swimmers. Consequently, USRPT is a swimming system that emphasizes technique over any other factor and it should be the central feature of any swimming program and all training sessions.

A further qualifier for the concept of technique has received little attention by swimming coaches. Craig and Pendergast (1979), followed more that 10 years later by Chatard et al. (1990), Toussaint et al. (1990), and Pelarigo et al. (2010) showed that stroke technique is specific to the velocity of swimming. The techniques, neuromuscular patterning, and phases of force application will be very different within a swimmer at 1.6 m/s than at 1.85 m/s. Part of the alterations in technique, particularly at higher velocities are caused by the exponential increase in water resistance with an increase in velocity. Within the same swimmer, the techniques of swimming 100 m and 200 m breaststroke differ because of the different swimming velocities in each race. The technique of swimming 50 m crawl stroke is very different to that used for 100 m.[7]

At a particular swimming velocity, the limbs and muscles function in particular roles with defined patterns that are peculiar/specific to that velocity. Energy has to be provided to enable the muscles to perform in the appropriate manner. The body has to learn how to consistently move with a neural pattern and how to distribute energy resources to support that pattern. The areas of the brain activated to do this are peculiar to the velocity performed. Alter the swimming velocity and i) the muscles adjust their functions into another appropriate manner to suit the changed velocity, ii) the body has to alter the provision of energy to the changed muscle fiber actions, and iii) the pattern of brain activity is changed so that it reflects only the activity of the resources for the altered velocity. And so it is with every velocity, a distinct pattern of brain activity is related to each swimming velocity that has been practiced. For unpracticed velocities, confusion in the brain and muscle function often occurs as the body attempts to cope with unfamiliar movement demands. Swimming training is best designed when it provides training stimuli that are as much as possible at the swimming velocities that will occur in races. All non-race velocities (i.e., non-race techniques) are a waste of time. If the brain is asked to do something it has never done before it overreacts. That results in: i) performances getting worse before getting better after sufficient initial familiarization (i.e., training); ii) the swimmer becoming tired very quickly until sufficient practice has been endured; and iii) the smoothness of an action is disrupted if a movement segment is changed (i.e., it becomes jerky). The question that should be asked of traditional coaches is: *"What is the value of not swimming at race-pace"*. If the answer involves some mumbo-jumbo about energy systems, or base, or oxygen reserves, etc., none of which will be correct, questions about the coach's competency and knowledge need to be asked. The energy supplied to muscles in swimming is specific to the velocity swum. Since the only important velocity is that which should be swum in a race, then race-pace swimming will yield the proper energy supply and the efficiency of that supply will be improved with specific training.

Technique instruction has been recognized as being important but has not been stressed as a major activity in training sessions. Counsilman (1968) warned against using technique instruction during a training session.

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[7] It is possible to compare the techniques over different distances within swimmers. The web site, *Swimming Science Journal*, *How Champions Do It* section (http://coachsci.sdsu.edu/swim/champion/table.htm) provides underwater analyses of many champion swimmers in important races. In some cases it is possible to discern that technique changes as a race progresses, something that has been reported in the literature (Oxford et al., 2010; Seiffert, Chollet, & Chatard, 2007).

> One of the criticisms of swimming coaches heard most often is that they don't work enough on stroke mechanics. Once the actual training season has begun, the coach is busy conducting practice with the emphasis on conditioning his swimmers, rather than improving their stroke mechanics. If he takes too much time from practice to work on stroke mechanics, he will not have his swimmers in top shape. True, he can drop a few words here and there, but he and the swimmers are primarily concerned with how they are swimming their repeats, and so on. The ideal time for the major portion of the stroke work in terms of motor learning and of time available is early in the swimming season, before hard swimming training has begun. (p. 189)

Fifty years after Counsilman's writing, knowledge of motor skill instruction and the various procedures involved with effective behavior change have grown remarkably. Counsilman's claims are no longer appropriate. The science of instruction of motor skills is termed *sport pedagogy*. A central feature of instruction is engineering the greatest amount of feedback possible during the practice of a sport. There are a variety of sources of reinforcement that still need to be recognized by the swimming community and integrated into effective coaching. Total swimming programs need to be structured in some coherent way – possibly by the development of a curriculum that covers all the competitive swimming groups in a program (Rushall, 2011).

Techniques in swimming do not only embrace surface-swimming stroke mechanics. The non-swimming aspects of turns, double-leg kicking, transitions between strokes in medley races, dives, finishing, etc. also need extensive practice time because they do determine a significant amount of a race's time. Practice time needs to be apportioned to allow sufficient practice to facilitate the improvement of these skills. The Rushall (2011) book actually was modeled for the competitive programs in the Forbes and Ursula Carlile organization (Ryde, NSW, Australia). A number of new USRPT clubs and coaches have taken that book as the coaching manual in their early years.

It is possible to teach technique throughout every training session. USRPT has as the first element of a training prescription, the element of technique to be emphasized in the set. Figure 3 illustrates the general structure of a USRPT program item. Often a swimming set is replaced by a skill-learning set that provides sufficient repetitions and reinforcement to have an impact of the skill level of most, if not all, swimmers.

Technique or Psychology Item	**Event and Stroke to be Swum**	**Repetition Distance**	**Maximum Number of Repetitions**	**Total Interval Time (work + rest)**
Explosive initiation of every stroke	200 BK	50	30	Time plus 20+ seconds

Figure 3. The general format of a USRPT item description showing the important elements that describe what needs to be known to execute the set correctly. Rushall (2015) explains how each element is introduced and explained to a group of swimmers.

The first emphasis in the holistic definition of USRPT is surface-swimming technique and associated racing skills. Without those features being improved continually in swimmers, the possibility of success and overall enjoyment from the sport is very limited. This writer asserts that if a swimmer does not have efficient techniques in swimming strokes and admirable levels of associated swimming-skill executions, that swimmer will not have the degree of satisfaction and enjoyment it is possible to have in the sport. Thus, changing the technique and skills of swimmers is the central most-important aspect of coaching USRPT.

Constructing, changing, and modifying techniques and skills in competitive swimming is totally dependent on the coach being an accomplished motor-skills teacher. Unfortunately, the vast majority of swimming coaches are not good teachers and that limits the competitive achievements of swimmers. If a coach is not a good teacher, swimmers will not learn good techniques. Since technique/skills development is the primary aim of USRPT, a poor teacher will prevent that aim being achieved. No matter what else is emphasized by a coach, poor technique swimmers will be deprived of what could be in their swimming experience. Consequently, the second most important aspect of USRPT is developing the pedagogical skills of the coach. That is somewhat addressed by Rushall (2011, 2013c).

The development of pedagogical skills and knowledge is perhaps the most difficult part of becoming a USRPT coach. Unless swimmers are exposed to environments that develop techniques and skills continuously, provide some mental activity guidance for every repetition, and employ powerful reinforcing contingencies other than a coach's feedback, there is little likelihood that any swimmer's full potential in the sport will be achieved. The onus is on the coach to work hard at self-improvement in pedagogical and coaching skills and the continual accrual of verified (i.e., scientific) knowledge pertaining to the sport. If swimmers are expected to improve in every USRPT session then coaches should be able to volunteer in what manner they are better coaches after each practice session. The alteration of coaching behaviors to the standards expected of USRPT coaches (Rushall, 2011) is perhaps the most difficult task to achieve because there is little commonality between them and traditional coaching behaviors and expectations. There are three levels of coach evaluation that can be used to assist USRPT coaches to measure improvements in their professional conduct and expertise (Rushall, 1994). At the most basic level, the *Practice Session Coaching Performance Assessment Form* (*PSCPAF*) can be used for self-reflection on coaching effectiveness and the inclusiveness of essential coaching behaviors displayed at a practice. It is hard for this writer to imagine any coach implementing USRPT without a yoked self-improvement commitment and program. If a coach is not a good teacher steeped in the scientific/technical knowledge of swimming, then a USRPT program cannot be provided.

The USRPT requirement of effectively teaching stroke techniques and racing skills as well as continually being engaged in pedagogical self-improvement are the first two of four requirements for identifying a *bona fide* USRPT program. They certainly do signify no commonality with interval training, HIIT, or traditional swimming coaching.

The third element in the USRPT structure involves psychological activities. Two general classes of psychological/mental activity should be considered. The first is the thought structures and content that should occur prior to and during a race. That content, originally termed pre-race and race strategies (Rushall, 1979, 1995), has been shown to improve swimming performances during practices and in races. As can be seen in Figure 3, the first element can be the thought content of races instead of technique. That makes a set of repetitions particularly specific to a race. Race-pace training facilitates the refinement of energy resources and technique as well as the thought content to be used in a race. Practicing and fine-tuning the physical and mental aspects of an intended race performance adds to a swimmer's efficacy for performing as well as providing a prediction of what the actual performance will be. Since psychological activities and content determine the outcomes of races, this feature is important and needs to be developed.

The second aspect of psychological/mental activity concerns all the non-race events and experiences associated with participation in the sport. This is not an element in the USRPT structure. However, there are many events outside of practice sessions and competitions that can occur and influence a swimmer's readiness to train and/or compete. A review of some of the analysis tools that focus on relevant and irrelevant competition behaviors is in the *Coaching Science Abstracts* (http://coachsci.sdsu.edu/csa/vol33/table.htm).

The final element in USRPT is physical training. Unfortunately, many coaches and *"scientists"* have focused on the method of conditioning as being the *stuff* of USRPT. Unfortunately, that error illustrates *ignorance* rather than knowledge. Every swimmer has a unique set of inherited physical characteristics which limit the degree of response to physical training activities. Since the most significant determinant of swimming success is technique, and techniques are specific to the velocity of swimming, it is important that as much training as possible be performed at a velocity that is most appropriate for each race. The velocities of races are very high and approach or exceed HR_{max} and/or VO_{2max}. That velocity is race-pace. As was shown in Figures 1 and 2, the method for achieving the greatest amount of work in a training session is to perform short-work short-rest repetitions so that lactate does not increase or glycogen stores decrease. Thus, performing ultra-short race-pace training is the avenue for experiencing the greatest volume of relevant training possible. That was the message communicated in the paper *Swimming energy training in the 21st Century: The justification for radical changes* (Rushall, 2013a). Unfortunately, that message seems to have been missed by many people involved in swimming. The benefits of USRPT over traditional training are extensive and impressive. As well, USRPT offers opportunities to practice activities (e.g., race-strategy content) that rarely are possible in traditional training.

If USRPT is criticized by anyone because of its training format, that critic reveals a lack of knowledge, understanding, and interpretation of the scientific literature upon which USRPT is based and upon which traditional training should be based. Forbes Carlile (2015) described USRPT as follows:

> USRPT is a technique-oriented system that uses a particular training format to maximize the opportunities for learning race-relevant techniques. Its second priority is to make coaches good teachers so that they can assist swimmers in changing their relevant techniques. Thirdly, since psychology determines the outcome of races, that has to be emphasized. Finally, conditioning is limited to inherited abilities and can be accomplished fastest and most effectively by ultra-short training.

Since USRPT requires only one neural fatiguing stimulus per event per practice session, swimmers must keep detailed records of all repetition completions, sets, target times, technique emphases, psychological element practices, and overall evaluation of the training session. Because of the demands of USRPT, swimmers are expected to improve in some way every practice session and they should be able to nominate the improvement without assistance from a coach. With a training session containing practices for several events, the measure of training volume is *number of strokes completed for an event*. Thus, *strokes per length at a particular velocity of a specific event* is another understanding of training that swimmers have to develop.

Glenn Gruber, a 65+ years masters swimmer from Pasadena, California in 2013 set a personal goal of breaking the world record for 400 SCm in his age-group. That was achieved early in March 2014. Glenn estimated that he completed 68K strokes at the intended race-pace. The number of strokes is meaningful for evaluating conditioning and technique changes. With no other basis other than a personal guess, this writer believes that to alter a technique feature that has been in existence for several years or more, it could take as many as twice the number of strokes needed to attain peak fitness to achieve the change. That means, if it takes 50K strokes to gain race fitness, it could take 100K strokes to change the nature of a propulsive movement if reinforcement is intermittent.

Concluding Remarks

USRPT is a technique-centered swimming coaching model. To assist swimmers to develop or modify techniques to exhibit more effective stroke elements, the coach has to be an excellent instructor of motor skills as well as a social-environment engineer. The latter requirement consists of establishing cooperative technique and skill evaluations and reinforcement interactions between swimmers that are always in place. When practices are oriented to particular times for races, every repetition in a USRPT set becomes meaningful. No set is performed without a goal and no repetition is performed without a well-reasoned time as a goal. For those race-specific elements to be transferred to a competition setting, practice is also needed in coping with and controlling situations that occur in the setting and in particular, each individual race. The teaching of those psychological structures is also an essential component of USRPT and effective coaching. The use of race-pace repetitions in ultra-short training sets is the best way to practice race-pace techniques and psychological elements. Ultra-short training is the format for achieving the greatest amount of very high-intensity (race-pace) swimming. It also achieves training effects faster than longer work intermittent training formats or distance swims. It makes a practice session efficient and yields outcomes that are measurable and appreciated by swimmers.

USRPT is not HIIT because it is specifically designed to achieve performance criteria. Most elements of that design existed well before HIIT became popular but is still ill-defined. The conditioning aspect of USRPT has elements that are in concert with the original formulation of interval training. It requires physical work in a short-work short-rest format. The recovery period however, is based on research (Beidaris, Botonis, & Platanou, 2010) that favors the interpretation of oxygen utilization mechanisms being the main drivers of race-fitness. Although the work periods develop an oxygen debt because the intensity of work uses oxygen faster than it can be replaced, the recovery period is sufficient to repay most of that debt and importantly, the stored oxygen resources within the muscles and blood.

The characteristics of USRPT recovery differ to those of classical interval training. In USRPT they are of a set duration. In interval training, recovery was determined by the return of heart rate from ~180 to ~120 bpm. As runners became more fatigued in a set of fixed work-periods, the heat rate return normally would increase in duration as the set progressed. That contrasts with the fixed duration of USRPT.

The conditioning aspect of USRPT better resembles the original formulation of interval training, particularly the repetition of work at a consistent level. It bears no relationship to HIIT. USRPT offers a set criterion for terminating the repetition work, that being when the performance standard no longer can be sustained. However, the primary focus of USRPT on technique and the other aspects of coaches' pedagogical development and swimmers' psychology (i.e., mental skills) sets it apart from being similar to any other coaching or physical training structure that has been devised. USRPT is a unique experience for swimmers, a challenging set of tasks for swimming coaches, and is based on published scientific works. The complexity of USRPT is such that it will never be possible to run an experiment comparing its effects against other training models. The demand for control of extraneous variables in an appropriate experimental investigation would be impossible to achieve. While some persons have stated that USRPT cannot be evaluated until it has been subjected to experimental evaluation, that really is evidence of a failure to understand USRPT and/or the requirements of good experimentation. The first step in evaluating USRPT is to read the publications on its development and implementation and determine if its structural elements are or are not based on objective science.

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