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USRPT AND TRAINING THEORY V:
THE SPECIFICITY PRINCIPLE

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The *Specificity Principle* implies that the maximum benefits of a training stimulus can only be obtained when it replicates the movements and energy systems involved in the activities of a sport. When a sport can be divided into particular components and tasks, the more they can be practiced; the better will be the overall performance. Research indicates that task repetitions should be as physiologically, biomechanically, and psychologically similar as possible to the sport performance criteria.

This principle may suggest that there is no better training than actually performing in the sport. However, it is not that simple. If a swimmer trained merely by performing full-race efforts, the demands would constitute an extreme load that could not often be repeated in a training session. The training stimulus would then be applied too infrequently to produce any marked training effect. It would be better for a coach to select portions of the race distance and repeat those until the performance standard could no longer be sustained. The dissection of events into portions of distances (interval-distances) allows a swimmer to be subjected to a substantial quantity of high-quality work than is possible in a full continuous competition-like activity. The interruptions between the repetitions serve as rest periods and allow some recovery. With sufficient repetitions, a swimmer is subjected to repeated exposures to stresses that approximate various stages of a continuous maximum effort race. This form of training allows an athlete to be appropriately loaded to improve on the specific energy and fitness demands of the competitive opportunities in swimming.

The evidence in support of the Specificity Principle is overwhelming. It relates to the muscle groups being employed, the muscle fibers and their energy requirements, and the velocity-specific performance techniques that mirror those of competitive races.

Muscle Group Specificity

It takes only a small change in the position of a movement to drastically alter the muscle groups involved in the action. For example, in a simple movement such as flexion at the elbow joint, the forearm could either be pronated or supinated. Electromyograph (EMG) studies have shown that when flexion is performed with the lower arm pronated, the smaller brachioradialis muscle is used to a greater extent than the larger biceps brachii. The situation is reversed when the forearm is supinated and the powerful biceps play the dominant role. This explains why more bar-chins can be completed with an underhand grip than can be done with an overhand grip on the bar.

The point behind that example is the manner of the exercise determines the exercise training effect. The sport of rowing requires flexion at the elbow at the finish position of the rowing stroke. Since holding an oar or sculls requires the forearm to be pronated, it would be more beneficial to practice elbow flexion exercises (chins, curls, etc.) with the wrists in that position rather than with them supinated. Although flexion of the elbow is used to describe the exercise irrespective of the forearm position, that does not mean that the training effects derived from flexions with the wrist in either position are the same. It is crucial for efficient use of training time that the muscle groups of an activity are trained in the same locus of movement and speed of contraction that will be used in the sport. Given that requirement, how could performing swimming-skill drills mirror the intricate movement patterns of velocity-dependent free-swimming techniques?

The postural position that is used in training also affects the type of training effect. Rasch and Morehouse (1957) reported that a training program that increased elbow flexor strength at the waist had no effect on the *"seemingly same"* muscular action when the arm was overhead.

Another example of the specificity of the strength training response was shown in a study of leg-squat training. The muscles are used in different ways in squatting and pressing, so quite different responses exist for the two activities. A much greater improvement in leg-squat strength than isometric leg-press strength was obtained. The muscular strength adaptations gained through squatting only partially transferred to the action of isometric leg-pressing (Thorstensson & Karlson, 1974).[1]

Isometric knee-extension training at the knee-joint angles of 15 and 60 degrees also produced quite specific training effects (Lindh, 1979). Training at the 15-degree joint angle produced a 32 percent increase in isometric strength measured at that angle. The improvement at the 60-degree angle was only 13 percent. On the other hand, training at a 60-degree joint angle produced a 30 percent increase and only a 10 percent increase at 15 degrees. A load is carried in a different manner by the muscles in the thigh when they function at different knee-joint angles. Hence, the training adaptations are specific to the nature of muscle-group involvement.

Another variable that affects the specificity of training is the type of equipment used. Pipes (1978) trained groups using the same movement pattern on Nautilus (isokinetic contractions) and Universal (isotonic contractions) weight machines. Strength increases of 25 percent on the training equipment were found to be only 10 percent increases if measured on the alternate equipment. Even though the exercises were visually similar, the actions required by the two different forms of apparatus were more different than they were alike. Martindale *et al.* (1982) showed that training on rowing ergometers, in terms of internal work, was very different from performing in a real shell. There are a number of examples of would-be rowers who can achieve

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[1] Using examples from sports other than swimming and with equipment of various forms is a deliberate attempt to impress the reader with the universality of the Specificity Principle for physical exercises/movements. It is a principle that is not favored by any one sport over one or others. When studies do report the transfer of effects, their experimental designs should be evaluated carefully because very often poor scholarship produces a false positive result.

high power outputs on rowing ergometers but are less effective on the water. Ergometer performances are related only to a minor degree to actual rowing.

It is not unreasonable to assume that land-based equipment testing and training is unrelated to race-quality swimming or at least no more than demonstrated with rowers. Costill *et al.* (1983) showed that in high performance swimmers the relationship between land-based power and in-water speed is an insignificant amount (*r* = .25). Sharp, Troup, and Costill (1982) showed that there was a relationship between single-arm pull power (not strength) on a Biokinetic Swim Bench and 25-yard swimming time which at first contemplation suggests generality between land-work and swimming. However, only 25-yards was swum which does not replicate the energy demands or proportions of energy types of longer events (i.e., 50 yards and up). Carl *et al.* (2010) found moderate correlations between bench-press strength and 25-yard swimming performance and tethered swimming. The percent of common variance between the activities was no more than 70%. Crowe et al. (1999) related dry-land measures of strength and power to swimming power (30-second maximal tethered crawl stroke) and performances over 50 and 100 m freestyle. The land and water power measures were related but only in females and the 1-RM latissimus pull-down related to performance. No power or strength measures in or out of the water were related to swimming performance in males. High-volume training and dry-land training demands were not related to improvements in USA national team members' swimming performances (Sokolovas, 2000). In female sprinters (N = 23) the number of hours of dry-land training per week was negatively correlated (*r* = -.438) with performance. Breed *et al.* (2000) observed that dry-land training improved dry-land activities but not the performance of swimming racing starts. Some studies could be misleading if taken at face value. Basgier *et al.* (2004) revealed that land-training improved the land-training exercises with swimmers as subjects. There were no results of in-water swimming performances (if indeed any measures were taken at all). The fact that the subjects were swimmers was immaterial to the thesis of the investigation. Wright, Brammer, and Stager (2009) also showed that training on a Power Rack increased stroke power and distance. Unfortunately, as with the previous study the Power-Rack changes were not assessed as to whether they transferred to free-swimming. There is no scientific evidence to support the hypothesis that altitude training is beneficial to swimming performance (Rodriguez, 2010). Havriluk (2013) measured hand-forces three times over a nine-month period in swimmers (N = 9) undergoing *"hard"* training. Force diminished as the months progressed. Five of nine Ss recovered strength after a taper to levels slightly better than values recorded at the training outset. Four swimmers did not even recover to their baseline levels. Land-training seemed to have no affect on in-water force generation. These investigations seem to offer insights that when taken collectively mean out-of-water testing and activities do not transfer to high-velocity swimming in time-trial or racing distances longer than 25 yards/meters.

Most coaches claim to be aware of the Specificity Principle yet violate it in training practices. For example, there is a widely held belief that training on one strength activity will transfer training effects to another even though the locus of movement and skill quality of the acts are dissimilar. Strength gained in resistance exercises supposedly can be re-educated into skill performance (for example, see Bompa 1986). Sale and MacDougall (1981) showed that assumption not to be supported by research.

It would appear that the many benefits of training reside in the neuromuscular patterning of activities, and this appears to be a critical feature when understanding the Specificity Principle.

Training activities should be analyzed to be qualitatively the same as those required for competition. Coaches are warned of the potential for supplementary/auxiliary training activities to produce competing and often-dominant neuromuscular patterns that reduce or even hinder performance. Some originally highly-skilled, world-record-setting swimmers have slowed because they substituted resistance-training movement patterns in their swimming techniques. Swimming with resistance-training patterns of movement was less efficient than natural-stroking patterns. This has important implications for training. There is the possibility that if supplementary training is sufficiently emphasized, artificial and inappropriate movement patterns will come to dominate the natural and efficient movement patterns of swimmers by supplanting those natural desirable patterns; performances would then deteriorate. In effect, a swimmer could finish up swimming with pulley-developed arm patterns as opposed to naturally correct swimming movements. Neuromuscular patterns for speed, strength, power, and balance are all dependent on the speed and pattern of movement of that activity. Costill, Sharp, and Troup (1980) concluded that swimming strength is best achieved by repeated maximum exercises that duplicate as closely as possible the skill of swimming. The most appropriate exercise that they suggested was a series of maximum sprint swims.

The more the training and competition activities differ, the less valuable will be the training activities for affecting real performances. The gradient of transfer value loss of a training effect between two activities is particularly steep. For example, activities that look similar, but are performed at slightly different speeds, are most likely to be completely dissimilar in their training effects[2]. This means that for every alteration of the speed of action -- and the same applies to path of movement or apparatus used -- there is a different neuromuscular pattern of movement developed in the brain. In essence, if the *"same"* skill is practiced at 10 different speeds, an athlete will develop 10 different skills and training effects.

Several endurance-training studies over a range of sports have found that non-specific training does not produce the same benefits as specific training. One of the first studies showed that on a running treadmill, rowers produced more lactic acid and performed worse than they did when rowing on a rowing ergometer (Brouha, 1945). Another study of training specificity showed that kayak endurance performance was enhanced by kayak training but not by bicycle training. Evidence of improvements in mechanical efficiency, anaerobic threshold, and VO2max while kayaking showed that adaptations only occurred in the specific muscle groups employed in kayak-training (Pyke, Ridge, & Roberts, 1976). After a two-month period of swimming training, a group of swimmers significantly improved their training responses and performance times as well as their VO2max in tethered swimming. No improvements were observed in running VO2max. The specific adaptations of swimmers were also seen in the measurements taken on the former great Swedish swimmer, Gunnar Larson. During the two-year period leading up to his medal-winning performance at the Munich Olympic Games, physiological measures obtained in a swimming flume reflected his training status throughout this period, reflections not evident in treadmill assessments (Holmer, 1974). Stamford *et al.* (1978) trained two groups, each on a different task of either hand-cranking or stepping. VO2max increased for each group in each

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[2] This paper assumes it is discussing serious competent swimmers. Following is a discussion of the Specificity Paradox which shows that beginning swimmer training effects, activities, and programs are mostly inappropriate for competent swimmers.

activity but there was no transfer of training effects in either maximal or submaximal work. What these examples, and the literature in general indicate, is that training effects are task specific and appear to be based predominantly in the musculature and representations in the brain.

Training energy systems on different apparatuses produced different training responses. Payne and Lemon (1982) conducted a metabolic comparison between tethered and simulated swimming ergometer exercise. For maximum exercise, some of the indicators (heart rate, ventilatory exchange, subjective assessments of similarity) were the same but the energy requirements were quite different. This suggested that simple measures might not be sensitive enough to discern more important energy requirement differences. Subjective assessments are influenced by many factors, including erroneous beliefs in the value of some forms of exercise. If these two forms of exercise are used as training activities for high-level swimmers, it must be asked, *"if both activities are so different, which of them is more valuable for training swimmers?"* The possibility that neither is valuable should also be considered.

The Specificity Paradox

Beginner swimmers benefit greatly from doing drills as part of their instructional process. It allows the learner to focus on an action-part that might be difficult to do if it were first attempted imbedded in the full complex cyclic swimming action. Similarly, an unfit individual might start jogging as a way of improving fitness to find that at that time the running also makes riding a bicycle easier. Part of the learning or initial adaptation challenges that occur when beginning a new activity shows they do respond to non-specific but allied activities.

As a new participant builds familiarity with an activity and develops some competency, the effects of non-specific activities no longer are so obvious. With a complex movement like any competitive swimming stroke, within the same individual some parts of the action might still be at the beginner stage while others have forged ahead to have a recognizable level of competency. When swimming crawl stroke, as a previous beginner improves the kick which might be of an average acceptable form, the arm actions could still be at the beginner level. The effectiveness of part-skill activities (i.e., drills) would vary with the competency levels of the parts of the total movement pattern.

Competent swimmers (e.g., those entering into serious training) will gain little from performing parts of a stroke in isolation (i.e., drills). Similarly, the early fitness gained after entering a serious training program will have only slight transfer to other activities. As experience with training improves, the value of part-learning experiences or *cross-training* for fitness diminishes.

Advanced or *elite swimmers* need to be exposed to training experiences that directly comply with the Specificity Principle. Techniques need to be altered and those alterations practiced while performing the whole action. Physical training needs to be applied to the actual muscle-part and muscle-group activations that are of the same velocity as those which would occur in swimming races. The vigorous debate of more than half a century ago over the part versus whole learning strategy showed that for cyclic activities (e.g., swimming, running, rowing, kayaking, cycling, etc.), when technique modifications are needed they should be attempted while performing the total action. As will be discussed below, specific changes attempted in competent/advanced performers require modifications in the neural patterns of activation in the brain associated with the full action.

With regard to any reaction to demanding physical exercise, Stegeman (1981) described training effects. As muscle adapts to exercise stress it cycles through a diminution in performance capacity caused by a training stimulus and recovery and overcompensation caused by the body's attempt to adapt to that specific stress. That leads to a continuous cycle involving natural breakdown and gain in performance capacity that result from *functional stimuli of a specific nature*. If strength stimuli are applied then only strength is improved; if endurance stimuli are applied, then only endurance is improved. The body adapts to adequately cope with the specific forms of exercise stress which are applied. The adaptive process does not include any capacity that extends beyond the specific training stress. Thus, there is no basis to expect training effects from one form of exercise to transfer to any other form of exercise. Training is absolutely specific (Noakes, 1986).

However, training is not very beneficial when stimuli are mixed. When training tasks vary and do not provide important repetitions or volume of an experience, the body continually attempts to adapt to changing conditions. While adaptations of a specific nature do not occur, general fatigue (e.g., reduced glycogen levels, accrual of lactic acid) usually increases. If the volume of mixed work is sufficiently high, a general change in the physical status of the body is achieved requiring restitution during recovery. Unfortunately, there is no accompanying skill or resource utilization improvement. Mixed programs are satisfactory for general fitness improvements. They are not beneficial for specific performance improvements.

The best description of the effect of mixing training stimuli is *"mixed training produces mixed results."* When specific-training objectives are desired, training stimuli should feature repetitions or extensive volumes without interruptions from other stimuli which likely would disrupt the adaptation signals being generated. Consistent stimulus demands need to produce a level of fatigue that debilitates performance to the level that a particular quality can no longer be sustained because of technique degradation and despite increased effort. That level is often termed the *"training threshold."* In USRPT terms, that is *neural fatigue*. It is harmful to fatigue athletes beyond that threshold.

The *Specificity Paradox* is that for beginning swimmers the variety of stimuli offered in their swimming experiences can be varied while at the other end of the competitive swimming spectrum the stimuli need to be specific. What works with and improves beginners rarely works with or improves advanced or elite swimmers. Unfortunately, that clear distinction is muddied in the swimming literature and swimming training advocacies.

Noakes (1986) discussed running but his assertions were equally true for swimmers. USRPT is fully prescribed for advanced swimmers, but is used to a lesser extent with younger (Rushall, 2014) and non-serious swimmers. What Noakes said and implied is particularly pertinent for strengthening the argument for the Specificity Principle in swimming.

In aerobic endurance training, mitochondrial adaptations occur only in muscles stimulated by the activity. The response is further limited to those fibers which are activated at the intensity level in the activity. Thus, white fibers are very unlikely to be stimulated to produce a training response in work that is consistently at or below anaerobic threshold. Those adaptations are only specific and do not generalize to other forms of activity that may use the muscle, and therefore muscle fibers, differently. For example, endurance gained from flat-track running does not generalize or facilitate hill running. In swimming, pool-training does not transfer completely to open-water racing. Different training intensities use different physiological mechanisms and therefore, produce different training effects.

Response systems are also dependent upon the mechanical function doing the work. For effective training at least the appropriate biomechanical actions (technique and its constituent neuromuscular patterns and pathways) must be maintained and repeated while the appropriate energy system usage is fatigued. Irrespective of the development level of an athlete's technique, when in a non-fatigued state, a swimmer usually works as efficiently as possible, even though the technique might include some *"errors."* With the onset of fatigue caused by a training stimulus, muscle fiber and then muscle recruitment occurs, eventually resulting in a degradation of movement efficiency no matter what the standard of technique that originally existed. In the very early stages of fatigue, a loss of efficiency can be stalled by the athlete consciously striving to maintain essential technique elements, a compensatory activity that lasts only for a short time. Physical fatigue gradually becomes more general and reduces movement efficiency. Consequently, it is not worthwhile to persist past that point with excessive fatigue that causes technical inefficiency when attempting to get the optimum benefit from a practice activity.

Once the activity's biomechanics are degraded, further physiological overload is not warranted because the body will be learning to energize an inappropriate and, very likely, counter-productive action that is nothing like that which is required for competing. Thus, for specific training to be beneficial it has to include both the biomechanics and energizing system of the intended competitive performance. For serious performers, that is the *Specificity Principle.* Unless a swimming coach is aware of the *Specificity Paradox,* errors in practice content and coaching behaviors/instruction are likely to occur.

The following is the important implication of the *Specificity Principle* and *Paradox* for coaches of serious swimmers.

> *When a program mixes training stimuli, it is likely that the body's response will be general and diminished over that which could be achieved through blocked, repetitive stimuli that are relevant for competition performances. A response system can only be stimulated optimally when it is exposed to repetitive work that requires skill technique maintenance in the face of increasing fatigue. Mixed work does not achieve that because both techniques and energizing capacities are varied, none being stimulated optimally, and so responses are not maximal. For effective coaching it is essential that "types" of work are programmed to provide optimal stimulation through the preservation of exact techniques with appropriate physiological overloads that replicate what is needed in competitions. There comes a time in a training segment where further work is counter-productive. That point is where performance and technique have deteriorated despite increased effort by the athlete. Coaches have to be "brave" enough to terminate training at that point rather than completing the segment as programmed* (Rushall, 2004).

The Specificity of Neuromuscular Patterns

Sensory Organs in the Skeletal System

The brain senses movements through three forms of sensory input. Signals from those mechanisms combine to promote movement patterns in areas of the cerebral cortex.

- *Muscle spindles* reside in the muscles and are responsible for relating information to the brain about current muscle length, the speed of muscle contraction, and the degree of stretch the muscle tissue can accommodate.
- *Golgi tendon organs* are specialized receptors in muscle tendons in close proximity to the region of attachment to muscle fibers. They respond to muscle tension and promote relaxation in the muscle being stretched if a threshold of stimulation is surpassed.
- *Joint receptors* provide information about the position of joints, that is, the posture of the swimmer. They reside in the synovial joint capsules and ligaments.

These three mechanisms provide the specific complexity of information about particular movements. They are the links between muscle movements and the brain's patterning of specific movement characteristics. The degree of sensitivity of this system of sensory organs is quite remarkable and it facilitates very refined movements if an individual is exposed to the appropriate learning and practice conditions. It is the uniqueness of the amount of information that is provided by particular movements that produces the specific nature of learning. Learning specificity is a survival mechanism because in a biological sense, it provides the basis for adaptation and for evolutionary development and existence. If an organism was not able to discriminate very minor changes in its internal and external environments, it would neither evolve nor survive. The body is oriented to discerning the differences between very similar movement patterns rather than generalizing common features.

Neuromuscular Pattern Specificity

The concept of all movement patterns being separate and specific has existed for a long time. In this day, little confirmatory research is conducted on the patterning of movements in the brain. It has become an accepted motor learning principle that all movements are specific and that the higher the level of proficiency of an athlete, the more refined will be the neuromuscular patterns. It is the neuromuscular patterns that govern high-level performance even in activities where physical effort is extreme (e.g., Grabe and Widule's 1988 study on weightlifting). As evidence of the universal acceptance of this concept, Luttgens and Hamilton (1997), in their valuable book on kinesiology, did not justify the principle of neuromuscular specificity but simply referred to it as follows:

> *Skillful and efficient performance in a particular technique can be developed only by practice of that technique. Only in this way can the necessary adjustments in the neuromuscular mechanism be made to ensure a well-coordinated movement* (p. 507).

The two authors repeated their acceptance of the specificity of neuromuscular patterning in their discussion of muscle strength.

> *Strength or endurance training activities must be specific to the demands of the particular activity for which strength or endurance is being developed. The full range of joint action,*

> *the speed, and the resistance demands of the movement pattern should be duplicated in the training activity* (p. 465).

Many auxiliary training activities for swimming are advocated, many driven by the profit motive rather than scientific fact. They need to conform to the Specificity Principle. In this paper, only a few works in the historical literature that led to this principle will be considered. While reading this section, one must consider how can the popular commercial aids that exist today (e.g., kick boards, flippers, hand paddles, drag suits, etc.) promote activities for swimming that conform to this principle? If they cannot, then they must be wrong.

Some Historical Elements in the Development of the Specificity of Neuromuscular Patterning[3]

The most impressive early discussions (~90 years ago) mostly involved Frank Gilbreth's recount of Sperry's work, which disputed *Poppelreuter's Law*. That work showed when an arm was extended vertically downward and the index finger slowly traced a 12-inch circle, a pattern of sequential firing of the shoulder muscles was displayed with most muscles assuming a propulsive (agonistic) function at one time and a control (antagonistic) function at another. However, when the same circle-tracing was sped-up, the sequence and functions of all the muscles were totally changed despite an observer seeing the "*same action*" done at a faster velocity (Arthur Slater-Hammel, personal communication, October, 1967). The complete difference between submaximal and maximal efforts doing the *"same"* activity is still being verified (e.g., Elmer, Peterson, & Marshall, 2014). Using arm-cycling, which is somewhat allied to the upper-body work of swimming, the change in effort levels showed maximum efforts recruited major muscles that were not used in the lesser-intensity work, had different muscle coordination patterns, peak EMG activity occurred in some major muscle groups, and the extent of muscle activations were also increased. When training at less than race-pace intensity, the technique bases (i.e., how and when the muscles work) do not train anything associated with the race-pace work. It does not prepare individuals to compete in the specific race.

Frances Hellebrandt (1958, 1972) summarized much of the main implications of the research on motor learning specificity that existed before the late 1950s. There has been little new information on this topic since then. Some of her conclusions and their implications are listed below.

> "*If muscles participate in more than one movement, as most do, they must be represented diffusely in the cortex. Presumably different centers connect via internuncial neurons with groups of peripherally disposed motor units. . . . motor units are activated in a definite sequence which varies with the movement elicited. As the severity of effort increases, those involved primarily in one movement may be recruited to assist in the performance of others*" (Hellebrandt, 1972, p. 398).

Movement patterns, not muscles[4], are represented in the cortex. Patterns are learned and those patterns are peculiar to every movement. Skilled performance improvements are continual

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[3] Much of this section is a repetition of the appropriate part of Rushall's (2013a) paper *Swimming energy training in the 21st Century: The justification for radical changes (Second Edition)*.

[4] The term *"muscle memory"* is nonsense.

refinements of the details governing the skill intensity, velocity, type of muscle contractions, and locus of movement. They are represented in the brain. No swimmer would improve swimming butterfly at race-pace without practicing intervals at race-pace (de Jesus *et al.*, 2010). To practice at another velocity would practice something different. Swimming techniques are peculiar to each varied velocity for each competitive stroke.

> ". . . *reflexes evoked under similar conditions are extraordinarily consistent. Indeed, they are so repetitive as to warrant designating them patterned movements. . . the fundamental unit of action may be thought of as a total response in which agonists and antagonists, synergists and fixators participate in balanced and harmonious activity. Partial patterns emerge secondarily, by virtue of special training, . .* " (p. 399).

Total actions (e.g., those to be used in a competitive setting) need to be practiced. The partial or isolated training of movement segments (e.g., drills, land-training exercises) would not replicate the unit function in a desired total competitive action. Thus, once techniques (total response patterns) are being refined, partial practices would serve no purpose other than to learn another movement. There would be no integration of the partial practice movement into the total response movement once an individual-determined level of swimming-skill competency is reached. The only way a highly-skilled swimmer can improve performances, is to specifically practice those performances. No auxiliary training activities would contribute to swimming skill enhancement once the skill has achieved a reasonable level of proficiency.

> ". . . *the sensory feedback coming from muscles, tendons, and joints greatly affects movement patterns. Central excitations have a tendency to flow always into stretched muscles. Thus, every change in body positioning alters the configuration of the next succeeding efferent response. It affects not only the muscles stretched, but all functionally related muscle groups as well. This means that a change in the responsiveness of one component of a movement-complex spreads autonomously to the other constituents*" (p. 399).

When a patterned movement is changed by conscious effort to alter at least one aspect of a stroke technique, the whole action is altered, usually to perform worse[5]. The practices of isolated drill elements or use of swimming equipment and then consciously implementing the experiences from the drills and equipment use into the established pattern would disrupt the pattern in its entirety. Thus, the changed element may be performed "*better*" but the other, previously acceptable movement characteristics will be altered for the worse. This is the conclusive argument against auxiliary training that is supposed to "*strengthen*" a swimmer or increase swimming velocity. Claims to produce beneficial changes in serious swimmers by doing something other than race-specific swimming should be treated with great skepticism.

> ". . . *willed movements which are new and unfamiliar always demand cerebration. They are performed at first with more or less conscious attention to the details of their execution. Once mastered, they operate automatically. Conscious introspection at this stage may even disrupt the nicety of an established pattern. After an act has become automatic, . . , it is less well performed if it must first be considered and analyzed*" (pp. 399-400).

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[5] To improve/alter an established technique, competent performers have to be prepared to perform worse for a period of time before they perform better than before the change. That leads to the adage; *"A swimmer has to get worse to get better."*

Conscious attention to details of an automated action will reduce the efficiency/economy of that action. There is a time before an important swimming meet when conscious attention to details of technique at practice needs to cease so that preparation can be perceived by a swimmer as consisting of "*good feeling*" techniques that are performed automatically. At some stage in a swimmer's career, the emphasis should switch from "*changes for the better*" to refinement of established skill elements and skills. When refinement is approached, it should involve mental preparation and recognition, specific-skill practice, and evaluation of swimmer-generated feedback against objective feedback (e.g., video analysis).

If competing movement patterns are learned through conscientious practicing of contra-specific water (e.g., drills, kicking, resisted-swimming) and land activities (e.g., weights, swim bench work), conscious attention in a race could switch to a less-efficient pattern of movement learned through the counter-productive activities, particularly if attention is on one segment of the complete stroke technique[6]. As attention then switches to other different skill elements, the economy of a performance is degraded. In races and at practices, a great deal of emphasis should be placed on the total swimming technique. If change is desired, then skill segments will have to be changed requiring both the coach and swimmer to endure and tolerate a decline in swimming performance until the change is incorporated successfully and the whole altered pattern, which is a new technique, is practiced sufficiently to surpass the level of learned performance of the previous form of the stroke. With young people, altering established skills is possible. However, with mature individuals there comes a time when no alterations of established skill patterns should be contemplated because there would be insufficient practice time to successfully incorporate the change and return to or better the previous performance level.

However, when fatigue is incurred, conscious attention to performance details produces a more efficient movement form than one that is executed automatically. Thus, there are times when the conscious control of performance movements is detrimental (e.g., in non-fatigued states) and times when it is beneficial (e.g., in states of high fatigue). In swimming, a loss of technique control should be used as the index of detrimental fatigue, recognizing that the fatigue could be physical, neural, mental, or combinations of all three.

Through practice, many activity patterns are learned. More often than not, families of movement patterns are learned to accomplish the same functional outcome. While a set of repetitions is executed in USRPT format, movement patterns will be evoked in series to avoid unnecessary fatigue in the central nervous system mechanisms and the skeletal structures used. In fatigue and stress, the recruitment of extra responses and neural patterns will be more extravagant because of learned facilitation. Much training is performed in fatigue and thus, more than restricted efficient movement patterns are learned to dominance. That mirrors what happens in a race. As a swimming race progresses, techniques change (Oxford *et al.*, 2010; Seifert, Chollet, & Chatard, 2007). If specific limited training had only occurred, that is, the body only knew a narrow band of efficient movements, then the recruitment (irradiation) would be minimal and movement patterns

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[6] Of particular importance for swimming is that if a change in a technique element is attempted, in accord with Newton's Third Law there will be a counterbalancing change in a technique element somewhere else in the stroke. For example, emphasizing kicking effort in crawl stroke will increase the amount of vertical (downward) force development in the arm actions to counter-balance the exaggerated vertical forces of the legs, probably reducing the amount of the propulsive (horizontal) force component in the pulling action of the arms.

would center on efficient movement. Adequate rests during practice should be provided to prevent a swimmer trying very hard to perform well when tired because too much fatigue inhibits the attainment of practice goals, reduces learning potential, and sensitizes the brain to new counter-productive/irrelevant experiences and neural representations.

Practice does not make perfect. Only practice that yields feedback about the correctness of responses can generate advances towards perfection. If practice activity content is largely irrelevant for competitive requirements and/or feedback is inadequate or non-existent, practice time largely will be wasted. However, individuals without external correct-coaching feedback do improve in performance but only to a certain level. Without instruction, individuals tend to adopt expedient strategies for movement control, which quite often are not the best or most economical movement patterns. This is why an individual can participate in masters swimming for 20 years, never having a coach, and gradually slow year after year in accordance with the aging process[7]. The expedient patterns that have been learned and perpetuated limit performance to that of a mediocre level.

For efficient and maximum performance ". . . *the kinesthetic acuity we should strive for is not enhanced general body awareness, but rather, a more sharply defined and specific sensitivity to what is happening in those key maneuvers upon which the success or failure of complex movement patterns may depend*" (Hellebrandt, 1972, p. 407).

The skill content of practices has to mimic that of competitive requirements if beneficial training time is to be experienced. It is wrong to practice something with good intent (e.g., "*I hope it will benefit the performance*") without being able to justify and demonstrate correlated transfer to a competitive skill and performance. It is wrong to practice a sporting activity if the skill amplitude and rate do not reflect the intended competition-specific qualities (Robb, 1968). If this dictum is not adhered to, much practice will be wasted or even will be counter-productive. It is quite possible that movements practiced could be so irrelevant that their impact on hoped-for race-specific movements would be so destructive that performance would be worse than if no practice had occurred.

There is a tendency in modern swimming for "*gurus*" to advertise their services for greatly increasing swimming performances for anyone willing to pay for those services. Mostly, such services offer one specific tactic, experience, or device for achieving remarkable claims. The theoretical and evidentiary reasons for the claims usually are not in accord with the known principles of human performance, and more specifically, motor learning.

In recent years, brain activity when performing or imaging a skilled movement has been viewed through the use of functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) scans (e.g., Ehrsson, 2001). Ehrsson showed:

i. Power and precision movements of the index finger and thumb of the right hand were controlled by different areas and patterns of activation in the brain. A power grip was associated predominately with contralateral left-sided activity, whereas a precision-grip task involved extensive activations in both hemispheres. Figure 5.1 contains a section of

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[7] USRPT has been shown to thwart the aging process and depending upon the quality of coaching, even reverse the hypothesized performance trends associated with aging particularly after a swimmer's age of 50 years.

the illustrations provided by Ehrsson (2001) which demonstrates the advancement in technology since Hellebrandt's work. The visual confirmation of the measured brain activity increases the reliability and understanding of the Specificity Principle in skilled and exertional movements. This work was also published by Ehrsson *et al.* (2000).

ii. Distinctive brain activity was also shown for the movement skills of synchronous and alternating finger tapping.

iii. The fontal motor areas of the brain are stimulated by both an illusory limb movement stimulated by vibration stimuli and imagined movements of the fingers, toes, and tongue. The patterns of stimulation are movement specific.

The latest research technology demonstrated by Ehrsson supports the specific movement representations in the brain for activities that are much alike. When movements are very different, brain activity is even more dissimilar. Further, it is a common procedure in swimming coaching to have swimmers perform their skills in the pool and to augment those skills with land-training. Often land-training activities aim to increase muscle group strength by performing activities in a postural orientation and gravitational experience, and loci of movements, speed and nature of contractions, effort levels, and performance outcomes that are distinctly different to the swimming experience. How one could believe that land-work augments and benefits water-work is baffling.

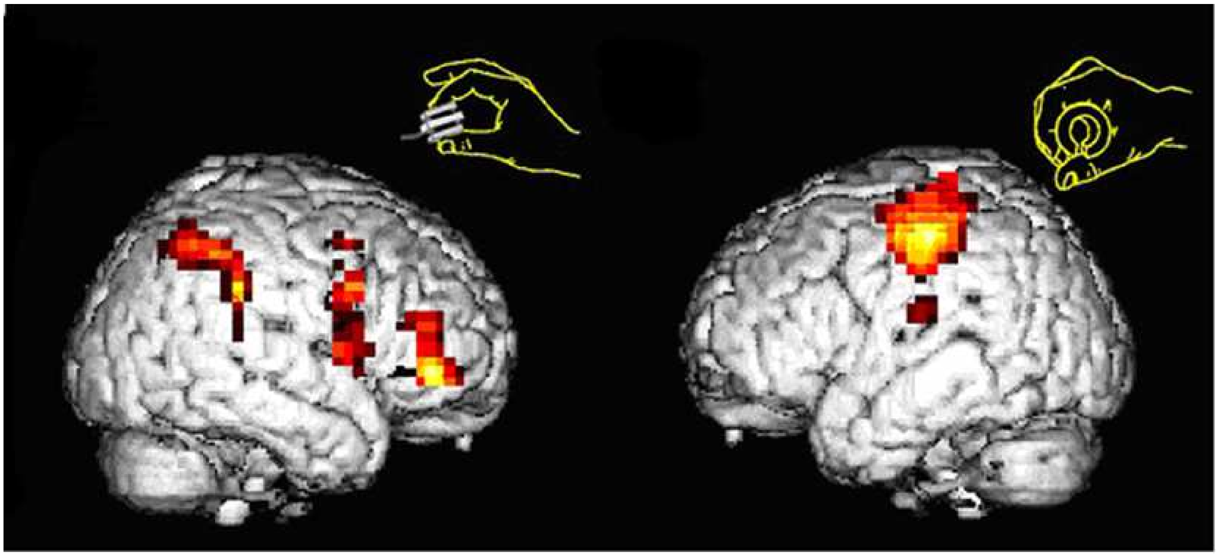

Figure 5.1. fMRI images of part of the specific brain activities associated with the precision index finger – thumb movement (leftmost upper line image) and power-grip movement of the same digits (rightmost upper line image). [Reference: Ehrsson, 2001. Permission granted for reproduction in this article (personal communication November 11, 2016): Image – H. Henrik Ehrsson; and copyright Karolinska Institutet.]

The following quote from one of the world's foremost motor learning/control scientists, Dr. Richard Schmidt, author of *Motor learning and performance: From principle to practice,* is most pertinent.

> "*A common misconception is that fundamental abilities can be trained through various drills and other activities...For example, athletes are often given various 'quickening' exercises, with the hope that these exercises would train some fundamental ability to be quick, allowing*

> *quicker response in their particular sport. There are two correct ways to think of these principles.*
>
> *First, there is no general ability to be quick, to balance, or to use vision...Second, even if there were such general abilities, they are, by definition, genetic and not subject to modification through practice...A learner may acquire additional skill at a drill...but this learning does not transfer to the main skill of interest*" (Schmidt, 1991, p. 222).

The specificity of movement patterns and control is a scientifically established principle of human exercise. It is the encoding of patterns in the brain that establishes the uniqueness of movements. There has been no wavering on this scientifically validated phenomenon over the past half-century, although minor theoretical incursions have been attempted. Yet, swimming practitioners persist in violating this basic principle of performance with dubious arguments, false premises, and distortions of facts. It is too well proven to concede that the scientists might be wrong. It is time for the practices and programs of swimming coaches to be brought into line with what is established fact. The training of swimming skills and energy provision and its variants has to be specific and whole. If effective technique-change work is not achieved at practices, swimmers will persist with undesirable stroke patterns which compromise propelling efficiency (Schnitzle *et al.*, 2008). The programming of appropriate transferable-to-race practice activities in an enriched milieu of correct swimming training is a challenge for modern swimming coaches.

Criteria for Judging Specificity or Commonality

When considering the worth of any activity for training competitive swimmers, several criteria should be considered. These criteria should be framed as questions about the swimming or non-swimming activity that is being considered as a potential auxiliary training exercise. The failure of any one of these criteria to be met by the potential training activity usually warrants its rejection as being potentially beneficial.

1. *The posture of the movement*. Swimming is performed in the horizontal plane and is fully weight-supported. The orientation of swimming requires a different set of recognizable sensory inputs to those of being vertical and having to combat gravity. Those differences will cause different patterns of brain activation and are likely to disqualify any vertical activity as having relevance (transfer value) for swimming. The postural position that is used in training also affects the type of training effect. Rasch and Morehouse (1957) reported that a training program that increased elbow flexor strength at the waist had no effect on the *"seemingly same"* muscular action when the arm was overhead. It is not hard to see the irrelevance of standing performing vertical rowing with a weighted barbell and swimming backstroke. Only exercises that are horizontal and in the water fulfill this single criterion.

2. *The locus/path of the movement technique.* The locus/path of the movements in the considered activity should replicate the movement paths of free-swimming. Reclining face down on a swim bench satisfies part of the first criterion but the solid bench surface causes movements to be restricted. The arm-pull movement paths on a swim bench are restricted from that which occurs in swimming. For example, in crawl stroke the shoulders and hips should roll together to as much as 45° to either side. The swim bench

prevents that and so arm actions would be different between the bench and free-swimming.

A further differentiating factor with a swim bench is the restriction/interference it imposes on the legs. Swim bench activities do not include kicking movements that mimic what occurs in full free-swimming strokes. The timing and paths of breaststroke arms are altered when no kicking is performed on a swim bench or in arms-only in the water.

While activities can be performed in a horizontal position, the opportunities to replicate sections of or even full stroking patterns are prevented. If different arm actions are occasioned by potential auxiliary activities, their transfer effects, if they occur are likely to be negative rather than positive.

3. *The muscles used.* Most sporting activities involve some control of movements. To control all or all of a section of a sporting action, some muscles perform agonistically (they produce the force) while others function antagonistically to control movement direction and when movements are near joint-movement extremes to prevent injury. Those functions and the timing, sequencing, of muscle involvements are a large part of skilled behavior. If they are not practiced exactly as they are in free-swimming, then they only have negative-transfer potential and should be avoided.
4. *The type of muscle contractions performed.* Exercise devices are available that guide movements to contract isometrically, isokinetically, or isotonically. Lindh (1979) showed the very limited effects of isometric training. Improvements in performance after training the knee-extensors at one angle transferred only partly to another close angle. Isokinetic training promotes movements at a constant speed. That is incongruous with most productive sporting movements that feature acceleration within the movement. Isokinetic-movement sensations differ noticeably from isotonic accelerated-movement sensations. Not only will movement patterns in the brain be caused by different muscle-contraction forms but the accompanying movement sensations will also be coded contrarily. Unless the type of movement contractions in a potential auxiliary activity are the same as those performed in a race-pace swimming activity, the potential activity should no longer be considered.
5. *The velocity of movement of the activity.* Differences in movement speed of seemingly the same motion result in complete changes in the roles of the muscles and timing of their activation (see the above reference to Gilbreath's work and his recount of Sperry's original research). Even in land-training activities, strength activities performed at moderate to slow speeds improve the strength of the same activities at those same speeds. On the other hand, explosive movements improve explosive speed work (e.g., time to peak activation, magnitude of neural drive (Folland & Fry, 2012)) and maximum force when compared to slower strength-work. Even if a potential auxiliary activity has movements that replicate the swimming stroke, if the speed and form of the auxiliary activity differ to stroking velocities and acceleration, the contemplated activity will be useless.
6. *The Resistance magnitude and type.* Applying forces to water in all strokes are intricate and sensation-drive actions. The concurrent feedback of the effectiveness of a competitive race-pace stroke has much to do with the actions that are made. Changes in customary sensations signal to a swimmer when technique is degrading and when

conscious effort to maintain stroking efficiency is warranted. No auxiliary activity could replicate that role of feedback. Consequently, one of the most critical control aspects of race-pace swimming will not be developed unless the experience of overcoming resistance is duplicated. The employment of additional resistance devices (e.g., drag suits) does not enhance swimming performances (Dragunas, Dickey, & Nolte, 2012).

7. *The opportunity to practice race-thinking or race-technique thinking when training.* An important factor that needs to be developed, but traditionally has been largely ignored, is the mental control and skills that should be used in a competitive event. Opportunities to practice the physical and psychological activities together are rarely provided swimmers. If auxiliary activities do not provide such opportunities then they will be deficient, despite most swimming experiences being similarly deficient in the psychological domain.

For each of the above criteria, if an auxiliary activity is considered and it is found to be deficient in one of these criteria, its use should be seriously questioned. If the activity is deficient in two of the criteria then its use should be rejected. For swimming programs that do include activities that are deficient in more than two of these criteria then their training effects will not transfer in any beneficial way to competitive swimming efforts and more than likely, they will be counter-productive and will distort swimming forms or interfere with potentially productive pool work. USRPT does not advocate auxiliary training because swimming is such a unique sport. Gains in swimming strength (Costill, 1998), muscle hypertrophy (particularly in age-group performers – Losey *et al.*, 2013), exact technique, and competition psychology practice, among other training effects, are provided by USRPT.

Examples of the Specificity Principle in Swimming

In academic circles, the Specificity Principle reigns supreme. Since Franklin Henry's destruction of the generalist position with regard to human abilities in the late 1950s and early 1960s, any attribution of causal factors in general and skilled human behavior to general factors is largely silent. In exercise science, investigations to see how one activity would influence another largely different activity have mostly continued to show there is an absence of commonality. The *Coaching Science Abstracts* (http://coachsci.sdsu.edu/index.htm) contains 161 abstracts of exercise science researches that test the amount of commonality between two or more entities either in causal or correlational studies. Occasionally, some research results produce what could be construed as a Type I error (i.e., the false rejection of a null hypothesis). Through chance alone occasionally contrary research results appear in the various communicative sources in the Academy. More often, contrary results are due to some methodological problem such as not using a control group that is equal to an experimental group in all facets other than the factor being independently manipulated. Other experimental gaffs concern the lack of control over variables that could affect the outcome of an investigation, experimenter bias that increases the likelihood of research results confirming the general beliefs of the institution/laboratory performing the research, and other influences that are discussed in the literature. The overwhelming proportion of research supports the contention that the Specificity Principle pervades all human endeavors, including swimming.

Noakes (2000) rightfully criticized the concepts of exercise physiology as they pertain to athletic performance and training. He defined five incomplete models that are currently taught in university classes but are insufficient to explain performance under all conditions. As well, research weaknesses were identified. That problem does not appear to have been addressed since publication. In university classes, learning is not 100% accurate or total. Consequently, less than precise understanding of the scope of knowledge required to adequately understand a phenomenon is what students take with them from the classroom. In sporting circles, *"education"* courses for coaches and officials are offered mostly by individuals with less than a total grasp of the concepts surrounding human physiology in motor tasks. The same could be said for biomechanics and performance psychology. The undesirable knowledge levels of sporting participants and *"influencers"* lead to erroneous diatribes being embraced as true and useful. In swimming coaching, that is very true. Dr. Frank Zatko (USA Swimming Coach, personal communication, 1996) communicated the following: "*I wonder if our sport of swimming tends to pass down non-scientific coaching errors that just become part of the foundation of the sport?"*

Although there are many, it is worthwhile to consider two erroneous coaching concepts that pervade swimming coaching and the profession's coaching education resources.

1. There apparently is a need to sound scientific when discussion functions of the human body. Pseudo-scientific explanations are used by coaches to justify erroneous and sometimes abusive coaching procedures. For example, swimming performances cannot be measured with the high degree of precision that is required in a laboratory and more so in the field. Training induced changes in swimming performance generally are not quantifiable. Direct, accurate testing is rarely possible. Consequently, physiological surrogates (e.g., VO_{2max}, VO_2) are used to predict changes in performance in swimming competitions.

   ". . . most training studies . . . have measured the physiological and biochemical responses of the human to training and have paid less attention (i) to the extent to which human exercise performance is altered by different training programs, and (ii) to the specific physiological adaptations which explain training induced changes in athletic performance" (Noakes, 2000; p. 124).

   Common physiological and blood-borne factors are embraced as being relevant variables for understanding and predicting swimming behaviors and performances when there is no supportive but impressive unsupportive literature to the contrary. For example, lactate testing was popular for a number of decades, principally the 1980s and '90s. Pyne, Lee, and Swanwick showed that lactate profiles obtained throughout a training season were not related to final competitive swimming performances. The role of lactate/lactic acid in sports performance mostly is not understood. Anderson *et al.* (2003) showed that only some physiological and some performance tests administered in a taper period were related to final swimming performances. Pyne, Lee, and Swanwick (2001) showed that fitness indicators changed, as expected, with training phases, but those fitness measures/changes were not related to final competitive performances, which did not change over a season. Lactates were one of the unrelated-to-final-performance measures. Aerobic measures are largely unrelated to training and competitive swimming performances (Montpetit *et al.*, 1981; Pyne, Lee, & Swanwick, 2001; Rowbottom *et al.*, 2001). Physiological testing during training yields no predictive value for competitive performances and could yield irrelevant directions for training alterations.

2. Coaches speak of physiological capacities as if they were engine-like entities. It is common to hear of aerobic training, lactate-training, etc. In speaking of aerobic training, there are tests (spurious at best) to assess swimmer's aerobic capacity, and large portions of a competitive season are dedicated to the development of aerobic capacity. It is as if the work being done by swimmers only involved aerobic factors. The truth is that in any movement, all energy sources are activated, rather extravagantly at first but gradually they balance-out to emphasize one over the other depending upon the intensity of training tasks. The belief is that the *"physiological aerobic capacity"* is a single source of energy that is available to swimmers. Coaches interpret training intentions and swimmer responses purely in terms of inspired amounts of oxygen. It is commonly believed that any oxygen capacity changes are available for use by any swimming task. How wrong that is. Oxygen provided by the circulorespiratory system is not the only resource that can be called upon by any task. There are two other sources of oxygen for use in swimming. First there is stored oxygen and if stimulated by the correct form of training (e.g., USRPT) will increase in capacity. The other source is the conversion of Type IIb glycolytic fibers to Type IIa oxidative fibers. That conversion occurs with specific training featuring extensive repetitions to neural exhaustion of one competitive stroke and performance intensity (i.e., race-pace). Too much swimming training is performed at a submaximal level so that the Type IIb fiber conversions do not occur nor is stored oxygen improved because inspired oxygen is used in the majority of extended tasks.

   Recent research has indicated that in a single swimming race in a pool, stored oxygen and the alactacid and aerobic energy systems are dominant while a considerable amount of Type IIa fibers developed through appropriate specific-intensity training add to the oxidative energy pool for specific-event racing. Those factors have to be trained through demanding repetitions of a set-level of swimming intensity (e.g., race-pace). Improvements in those factors associated with one event will not transfer to other events in any major way unless race-pace work has also been experienced for those other events. The physiology of traditional swimming practices is discretely different to that of racing because they focus mainly on circulorespiratory adaptations. As well as those *central* adaptations, a substantial amount of training effects occur in the musculature (i.e., the *periphery*). Thus, traditional practices are largely irrelevant for racing and do not provide an avenue for major race improvements because of their limited training effects.

It is incorrect to speak of training the aerobic system or the lactic acid system because such systems do not exist as individual entities. What is correct is to speak of training activities that will then draw upon the body's resources and mechanisms to fuel and energize those activities. That energizing is specific to an activity. For *similar activities* there is the possibility for some of the resources being shared but that proportion is likely small. Slight changes in an activity promote the need for different energizing resources for the muscles and muscle functions that differentiate the *similar activities*. The work of Rasch and Morehouse (1957), already referenced above, showed that the same or very similar arm flexions at the waist and overhead did not transfer training effects measured as strength. The change in posture altered the arm function to all intents and purposes completely.

Some conditioning implications for swimmers can be drawn from the literature.

i. For swimming velocities that are moderate to light, as a guideline that is below the anaerobic threshold[8], aerobic resources are primarily central and remain in the realm of the circulorespiratory endurance system. With that training, oxygen is inspired to satisfy ongoing needs. Typically, that is what is measured in a VO2max test apart from a small amount of Type IIa fibers and basic stored oxygen that exist naturally.

ii. Once training intensities rise above the anaerobic threshold (metabolic equilibrium), swimming techniques change markedly causing a concomitant change in muscle function and intensity of use (Pelarigo *et al.*, 2010). At those higher intensities, inspired oxygen is insufficient to support the muscular needs and other resources are recruited. Type IIb (fast-twitch glycolytic) fibers are pressed into service and many are changed to Type IIA (fast-twitch oxidative) fibers. The added oxidative resource improves the endurance capability of the performance at the intensity with which the changes were provoked. The specificity of the alteration suggests that the most relevant exercise intensity for swimmers training to improve competitive performances is race-pace. Every racing distance requires different intensities and modifications in techniques and so training would be most expedient if it were done at the different race-paces for the distances and strokes of competitions.

iii. Different forms of training provoke different adaptations of energy resources. Some training formats are less efficient than others for influencing changes. Interval training is better than continuous training at a particular race pace. Short-work short-rest interval training (USRPT) is more efficient for promoting training adaptations than longer-interval and longer-rest interval training. The repetitive stop-start of the interval structure continually stimulates the use and restoration of stored oxygen in the blood and muscles (Astrand *et al.*, 1960) which results in an increase in the amount of stored-oxygen resources available to the swimmer when performing at the high-intensity and stroke technique used. As well, the USRPT format facilities a greater volume of race-specific pace and techniques than other formats (see Rushall, (2013a), which discusses the above mechanisms).

iv. The above guidelines for training should be applied to individuals. If one program attempting to institute higher-intensity work in short-work short-rest interval training is applied to a group of swimmers, some successes but more failures would result, as was so clearly illustrated by Howat and Robson (1992) who evaluated aerobic training stimuli applied to a group.

It is difficult to write a totally inclusive article that would embrace all the pitfalls of swimming coaching knowledge, practices, and education as well as indicating strengths, which unfortunately are overshadowed by the former. Within the publications concerning USRPT (http://coachsci.sdsu.edu/swim/usrpt/table.htm), many other problematical areas are discussed. For this *Swimming Science Bulletin*, the focus will return to and remain on the *Specificity Principle.*

Specificity of Technique

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[8] The anaerobic threshold that is measured is dependent upon the testing protocol used. There are a variety of protocols none of which have been shown to be *"true"* and the others *"false"* (Oliveira *et al.*, 2010).

The energy demands of each competitive stroke differ, which results in different rates of fatigue (White & Stager, 2004). Not only do the strokes differ but also the technique modifications demanded for different velocities within the strokes also differ. The technique of a competitive stroke depends upon the velocity being swum (Chatard *et al.*, 1990; Roels *et al.*, 2005; Rouard *et al.*, 1977) as does stroke efficiency (Toussaint *et al.*, 1990). It is important for a coach to decide why swimmers are participating in a program. The overwhelming majority of swimmers are endeavoring to improve their competitive times and to be successful in the sport. Given that, it would seem reasonable to develop a program that trains swimmers for their respective events as efficiently and comprehensively as possible. USRPT is the format and structure that satisfies endeavors to achieve that outcome. Traditional swimming coaching/training does not do that because of the frequent violation of the Specificity Principle in many regards. There is no escaping the specificity of technique for race-pace swimming. To swim at other than race-pace velocities is to train for swimming that is not competition-specific. That has partly been recognized by the now common term *"garbage yards"* which is spoken more by swimmers than coaches. There is no physiological or biomechanical reason for persisting with aimless, principally long swims.

Further evidence of technique specificity exists. If training units for a stroke differ in intensity, one level being heavily aerobic and another being anaerobic-aerobic, then the techniques differ (Wakayoshi *et al.*, 1996). Technique contributes more to racing performance than does land-based strength training (Havriluk, 2010). To evidence how much skill techniques change with task alterations, de Jesus *et al.* (2011) showed that simply placing the feet at different levels above and below the water line produced significant alterations in how a backstroke start was executed. Many coaches have stressed stroke length as being the major technique characteristic, particularly in crawl stroke. However, stroke-length emphases at one time did seem to be worthwhile but now in modern racing, stroke rate is possibly more important than stroke length (Hout-Marchand *et al.*, 2005).

In swimming races, as fatigue builds the energizing of muscles to perform an exact technique becomes increasingly difficult. As swimming velocity changes throughout a race, technique modifications occur (Seifert, Chollet, & Chatard, 2007). In reality, the technique of a swimming race is a *family of slight variations in technique* rather than an exact single skill. To accommodate that phenomenon, repetitious training aiming to maintain a particular velocity of progression in the face of mounting fatigue needs to be provided. USRPT provides that experience.

Treffene (2010) advocated race-specific swimming paces for training with an emphasis on technique should be programmed in judicious work and recovery sets for the best results for serious swimmers. USRPT does that. It is interesting to note that Rushall and McWhirther (2011) independently arrived at the same basic structure for serious swimming training at the same time as Dr. Treffene.

Irrelevance of Auxiliary Exercises

The velocities of a variety of crawl stroke drills were slower than a reference technique. The roles and use of muscles and the manner of energizing function were different to a comparative model of front crawl swimming. Not only were the forward velocities of the drills slower but so too were the involvements of the shoulders and hips in coordinated rotation. The drills evoked slower movements but the sequencing of the drill movements was not significantly different from the reference technique (Arellano, Dominguez-Castells, & Perez-Infantes, 2010).

When crawl stroke arms-only and legs-only exercises were performed, neither reached the same energy demands or progression velocities of a full-stroke at 100-m effort level. Since the arms and legs work together in crawl, with the legs primarily promoting streamline by counterbalancing the vertical force components created by the arms, each performed in isolation will cause their form of function to differ from when involved in a full stroke. Those alterations would promote training effects that have no use in full-stroke swimming (Rodriguez *et al.*, 2010). Konstantaki, Winter, and Swaine (2009) evaluated the effect of training 20% of the weekly distance using arms-only. Arms-only conditioning and performance improved in the arms-only tasks but there was no transfer of that specific training effect to free-swimming. *In situ* gas analyses of swimmers usually require a swimmer to wear a breathing apparatus. When a respiratory valve is used, a different pattern of breathing and level of work is produced (Strumbelj, 2007). That also suggests that the use of snorkels in practice would also introduce irrelevant technique changes into crawl stroke free-swimming.

Another popular auxiliary training activity is tethered swimming. Some form of elastic tubing, normally surgical tubing, is tied to the swimmer and an anchor point on the pool. Swimmers swim to stretch the tubing until progress is stationary. Gourgoulis *et al.* (2010) found that in crawl stroke, the angle formed between the resultant force vector and the axis of swimming propulsion was decreased significantly in the pull phase resulting in the resultant force being steered more in the forward swimming direction. Using that device practices an incorrect technique that should not be transferred to free-swimming. Sexsmith, Oliver, and Johnson-Bos (1992) evaluated and compared the effects of surgical tubing and the Biokinetic Swim Bench on front-crawl swimming. Each evoked very different responses. Which was more useful? Is either useful? The different responses mean that both cannot be of equal value. If the responses were so specific, would not it seem possible that swimming itself is equally specific and unlike either exercise? That study supported the Specificity Principle of training by showing the two auxiliary training forms did not replicate free-swimming and each produced unique distortions of desirable stroking characteristics. In a similar vein, Payne and Lemon (1982) compared tethered and simulated-swimming ergometer exercises. Despite the apparent similarities of HR_{max}, VEmax, and subjective assessments of effort expended, energy requirements, at least during maximal exercise, were quite different. The same question could be asked of those activities: *"which is more useful or is either useful?"* Rodacki *et al.* (2013) contrasted tethered and free-swimming tests at 200-m pace and duration. They found that propulsive forces decreased from the beginning to the middle of the trial while stroke rate decreased at all stages of the tethered-swimming test. Peak force was the only propulsive tethered-swimming parameter positively but lowly correlated with free-swimming velocity. Tethered-swimming stroke rate was positively correlated with free-swimming during the middle assessment in the two tasks. Only at the middle assessment was there a relationship between the stroke rate of tethered-swimming and 200-m free-swimming. This relationship increased during the first 50m of the free-swimming task and may be explained by the fact that measurements performed at earlier stages of the test may not necessarily represent the whole swimming task (i.e., the entire 200-m FS race). The few relationships found were overwhelmed by the absence of relationships between the task performances and factors involved in the techniques used in those tasks. For example, the fatigue experienced in tethered-swimming does not mirror that which occurs in a 200-m swim. Maglischo *et al.* (1985) evaluated both assisted- and resisted-tethered swimming on butterfly strokes. Both activities altered the free-swimming techniques of four male and two female swimmers. The changes were:

i. Sprint-resisted training caused shorter and slower stroking.
ii. Sprint-assisted training increased stroke rate but only by shortening stroke length and not by changing hand-velocity.
iii. Stroke mechanics were changed in both forms of training, casting doubt on the efficacy of both forms of training for butterfly stroke racing.
iv. This study could be considered an indictment of these training methods. Each forced swimmers to adopt less efficient mechanics.

Douda *et al.* (2010) evaluated predictors of performance in pre-pubertal and pubertal male and female swimmers. Of all the anthropometric, body composition, and strength factors, tethered-swimming force explained the greatest amount of variance in 50-m swimming performances. The amount diminished from pre-pubertal to pubertal swimmers. The lack of association between the structural factors of swimmers with their 50-m performances, and the diminishing relationship attributable to tethered swimming strength, indicates that other factors influence sprint performance in swimmers with increasing age.

Hand-paddles are a popular training device. Ogita, Onodera, and Izumi (1999) evaluated the effect of hand paddles on energy release during supramaximal swimming. The use of paddles produced inappropriate swimming speeds for particular metabolic effort levels. The late Forbes Carlile tested his swimmers using paddles and pull-buoys and compared their experiences to crawl-stroke swimming over 400 meters. All swims were instructed to be at 85% effort level. At the completion, swimmers rated their preference of equipment. All swims using paddles or pull buoys were faster than free-swimming. The preferences were paddles first, pull-buoys second, and free-swimming last. When questioned after the tests, swimmers gave the principal reason for choosing the equipment was that swimming was easier (Forbes Carlile, personal communication, circa February, 1985). Given the specificity of neural coding of movement skills, it is hard to determine why a coach would allow valuable pool time to be wasted performing irrelevant activities using equipment.

Drag suits are supposed to increase the active drag on swimmers as they progress forward. Somehow, making swimming harder is supposed to translate into better competitive performers. Dragunas, Dickey, and Nolte (2012)[9] evaluated the effects of drag suits on sprint swimming. No benefit was found. There is no value in wearing such suits because they do not help a swimmer's performance. It is possible that with more prolonged use they might even harm performance. Although the authors recommended using the ineffective drag-suits, one has to wonder why use them at all? All they do is create a different set of experiences for the swimmer which would disrupt free-swimming sensations such as *feel for the water*.

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[9] This study was published with some descriptive errors contained in the dialog. Corrections were agreed upon between the primary author and this writer after a personal communication.

A novel approach to swim-training activities was to perform in-water plyometrics. An evaluation of the value of such activities was performed by Wilson, Adams, and Stamford (2004) using age-group swimmers. No improvements in swimming performance features in the swimmers were observed.

The above sampling of auxiliary exercises showed no benefits from any of them. In reality, one should not be surprised. What is the potential benefit of distorting an activity to how it should be performed in competitive settings? If it is believed that distorted swimming experiences are somehow beneficial to free-swimming race-pace performances then the factual evidence to the contrary has to be ignored. The sampled researches reported in this section have been objectively obtained and therefore, should be considered as truths. Why a coach would opt for a personal non-evidentiary belief (i.e., the use of equipment and stroke distortions is good for free-swimming) over true evidence is another reason to be baffled by decisions made by many traditional swimming coaches. If auxiliary exercises are to be beneficial for serious swimmers, there needs to be an explanation of how the transfer of benefits occurs. The neurophysiology of learning does not suggest any mechanism and to the contrary has only shown that all exercises are discrete.

Kicking Exercises and Practices

Free-kicking or supported-kicking exercises are part of many traditional swimming coaches' programs. Somehow, kicking in isolation is supposed to assist free-swimming performances in competitions. There is no dispute that the breaststroke kick during the stroke and double-leg kicking underwater are propulsive and contribute to competitive performances.

What needs to be considered is the role and effects of isolated kicking practice items for serious swimmers performing front crawl, backstroke, and butterfly kicks. The first hurdle to be overcome is the common belief that in those strokes the kicking actions are propulsive when involved in the free-form of their swimming.

Isolated-kicking speed is only related to physical parameters over short distances (e.g., 25 yards). The relationship is reduced and non-significant with longer distances (Mookerjee *et al.*, 1995). The kicking variable associated with short-distance crawl-stroke swimming was leg-speed. Peak-velocity training might be trained using isolated kicking drills. The leg-speed variable is understandable when considering all-out 25-yard sprinting. The faster the legs move up and down, the shorter the time to execute six kicks.[10] Leg-speed is negated if the kicking action is big, which would require longer time to complete the set of six kicks. One set of kicks is performed for each full stroke cycle. When sprinting 25 yards, the higher the stroke rate, the more likely a swimmer is to achieve a high forward velocity. Although it happens often, the executing of a complete kicking cycle should not restrict any possible arm-rate. Thus, for 25-yard crawl-stroke sprints, the kicking action should be small and fast to minimize the time for a full cycle to be completed. For training, there would be no point in performing slow-kicking other than as an unrelated-to-swimming recovery activity. It seems that kicking speed (i.e., *turn-over speed*) might be helpful for 25-yard sprints but not for races of longer distances.

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[10] A small minority of sprinters use a four-beat kicking action per full arm cycle.

A second feature that needs to be shown is that the legs and feet are in positions that will create forward thrust throughout the kicking cycle. Brief positions that seem like they might produce some propulsion are ineffectual because of the time-lag that it takes to develop propulsive forces in fluids. Figure 5.2 illustrates the terminal positions of the downward kicks of two Olympic 400-m champions. Both actually have their feet in positions that produce resistive drag. For the minor time in those positions, the kicks are working against forward propulsion. In crawl stroke, it is difficult to imagine the legs and feet ever being in a propulsive position after the effects of cavitation disappear.

The *Swimming Science Journal* (http://coachsci.sdsu.edu/swim/index.htm) contains a section (*How Champions Do It* http://coachsci.sdsu.edu/swim/index.htm) that displays basic biomechanical analyses of many Olympic and World Champions' strokes in their winning finals. In not one crawl-stroke, backstroke, or butterfly-stroke analysis are the legs seen to provide propulsive forces. Rather, the role of kicking in those strokes is to counter-balance the vertical force components produced by the arms. That counter-balancing function serves to maintain swimmers' streamline which reduces frontal/cross-sectional resistance.

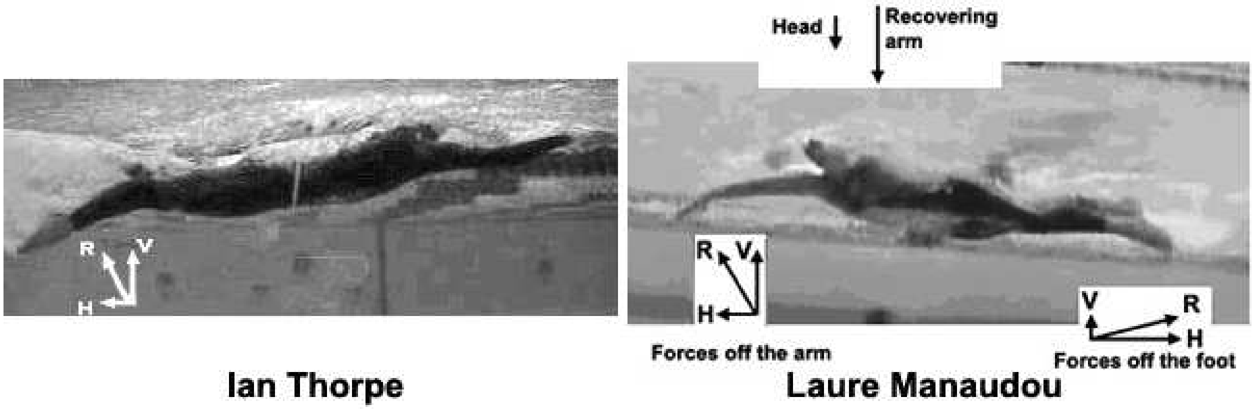

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Figure 5.2. The terminal kicking positions of two Olympic 400-m champions. The foot and leg positions actually produce forces (see the vector figures) that work against forward propulsion. Both pictures were extracted from videos of their Olympic Final swims.

Konstantaki and Winter (2007) evaluated if there were any benefits gained from emphasizing kicking-alone at practices. No transfers of any effects to free-swimming were recorded. The lack of effect should not be surprising. When kicking free or with a board, the function of the kick is to produce propulsion. When in full free-swimming of the three strokes in question, the function of kicking is counter-balancing vertical forces produced by the arms in and out of the water. Both are discrete kicking activities. No mammal has the same or similar movement patterns in their brains to produce two distinctly different functions. Board/free-kicking is not related to full-stroke kicking. No benefits for full-stroke swimming should be expected from isolated kicking activities. This fact was investigated by Deschodt (1999). It was found that the kicking action in crawl stroke was not propulsive to any significant degree. Rather, it facilitated better arm actions, which in turn increased propulsion and improved velocity. Brooks. Lance, and Sawhill (2000) found that kicking is not a source of propulsion in free-swimming.[11]

Rushall (2013b) analyzed the basic forces produced by a kick-dominant female 2012 Olympic Games Trials qualifier. Figure 5.3 and the accompanying quote are from Rushall's book.

> *In the series of frames in the collage, the details of the right leg are clearer than for the left leg. It seems both legs kicked in a similar manner.*
>
> - *Frame #1: The right leg kick is at the bottom of its downbeat. In this position the right leg cannot be propulsive. The amount of "milky" turbulence[12] on the rear of the foot and ankle shows that considerable resistance has been created by the front of the foot and ankle. The swimmer's posture is flat, suggesting that the power for the right arm would come almost completely from the internal rotator muscles of the shoulder (see Microcycle 3). The left arm is half-way through its sweep and is sliding upward. The depth of its trailing turbulence indicates a stroke with a lot of verticality and less than admirable horizontality. The right arm is just entering. The kick does not appear to be functioning in a counter-balancing role. The bottom half of the left leg is above the water surface (it is "kicking air").*

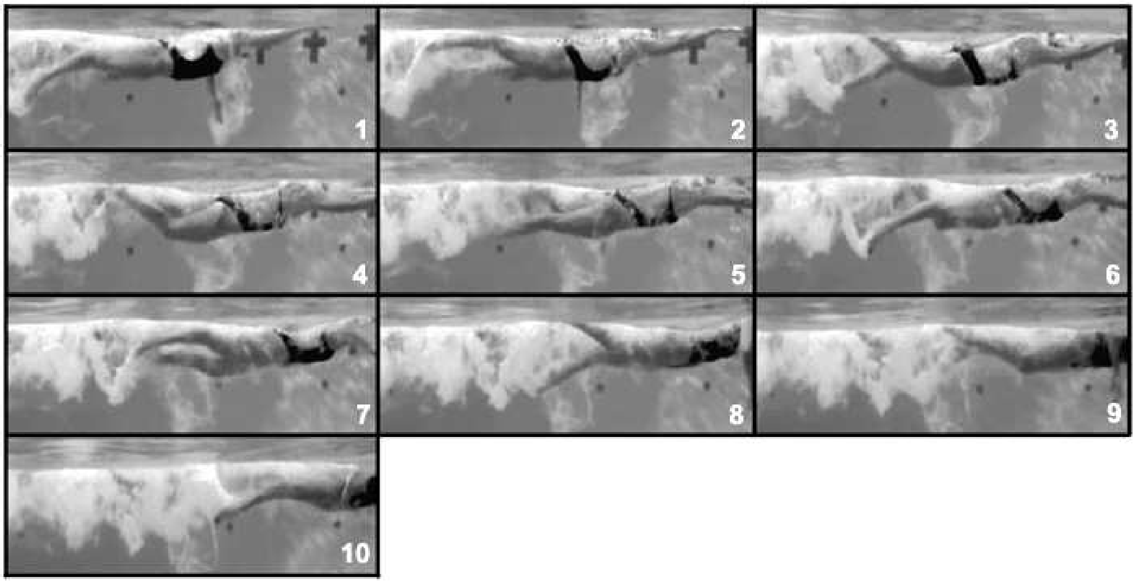

Figure 5.3. Kick-dominated crawl stroke in a female 2012 USA Olympic Games Trials qualifier.

> - *Frame #2: The right leg rises and creates considerable downward vertical force, which would provide no beneficial propulsion. The left leg is halfway through its downward kick. [By acting opposite each other, it is likely that both kicks are counter-balancing their excessive irrelevant force productions.] The entered right arm is suspended near the*

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[11] The reader is reminded that the kicking being discussed here is restricted to crawl stroke, backstroke, and butterfly stroke.

[12] The pressure in milky or turbulent water is less than in undisturbed water. It is difficult to discern if any of the turbulence consists of cavitation *"bubbles"* or diffused light from the water's movement.

surface and the left arm has risen further (instead of pushing back to a desirable end-of-stroke position).

- *Frame #3: The right leg is positioned to "kick air" and the left leg is at the bottom of its downbeat. In this position, the left leg is creating forces that have a notable rearward action and therefore, hinder the swimmer. The back of the right leg has increased the frontal resistance of the swimmer and hinders progress. The right arm is still suspended.*
- *Frame #4: The right leg begins its kick by flexing at the knee and hip. The knee drop disturbs streamline. The right lower leg is breaking the surface and will cause cavitation. Although the leg might be oriented to exert a small horizontal force backward, its effectiveness is greatly reduced because of turbulence in the top ~4-6" of water and cavitation. The right arm has been lowered slightly.*
- *Frame #5: The right leg extends at the knee placing the foot and lower leg in a position that generates mostly all vertical force and a small retarding forward horizontal force. The right arm begins to move.*
- *Frames #6 through #10: The ineffective kicking continues for the six-beat count. The action of the right arm is tied to six kicks. For a full two-arm stroke cycle, 12 large kicks would have to be executed.*

From this set of frames, the following features can be inferred.

i. *The excessively deep kicking action is mirrored by an arm action that goes deep and then slides up from the deepest point to exit. Optimal horizontal propulsion is not developed.*
ii. *The arm waits in a forward position, then does its deep stroke, and is timed with the duration of the six-kicks. The arm action is restricted to how long it takes for the kicks to be performed and because of its depth suggests that the arm is counter-balancing characteristics of the kick, rather than the other way round. With that interpretation, it is projected that the swimmer will never rise to the heights of more successful arms-dominant swimmers.*
iii. *Body roll is hardly perceived. It certainly is not performed to the extent justified and described in Microcycle 3. This also verifies that excessive kicking restricts the performance of good body roll and arm actions.*
iv. *The obvious "hard work" of the kicks performed by this swimmer results in very little, if any, productive work. Thus, the energy available for propulsion will be reduced by the irrelevant work exhibited in this swimmer's kicking.*
v. *Hard kicking increases resistance at a much greater rate than any potential propulsion or small fast kicking.*
vi. *The time after the left arm has exited (Frame #3) to when the right arm begins to be pushed down (Frame #6) is a period where no propulsive forces are generated and would cause the swimmer to negatively accelerate in that inertial lag.*

There is no value or justification for performing a "big kick" of this form. Hard kicking increases resistance at a much greater rate than any derived benefit. The above factors pertain to crawl stroke, backstroke, and butterfly stroke with adjustments and modifications of the presented content being made for backstroke and butterfly stroke. In those three strokes, kicking should only counter-balance arm actions to foster arm-dominant stroking patterns. Kicking should be neither dominant nor considered propulsive. From a swimmer's

> *viewpoint, the effort put into kicking should never be greater than the effort employed in the arm actions. Preferably, the kicking effort should be notably less than the arms' efforts.*

Double-leg underwater kicking bears no relationship to double-leg butterfly stroke kicking (Houel *et al.*, 2010). Many swimming coaches erroneously refer to double-leg underwater kicking as *"butterfly kicking"*. Training for double-leg kicking after starts and turns requires different training stimuli and technique features to what happens naturally in butterfly swimming. Similarly, with backstroke kicking-only, the actions of the legs and feet are different to what occurs when swimming the full stroke. The *How Champions Do It* web site clearly shows the lack of propulsive positioning of the legs and feet in those two strokes.

Dry-land Training

Many traditional coaches require their swimmers to participate in dry-land resistance training programs. The purpose behind such programs usually aims to improve swimmers' strength. Rushall, Marsden, and Young (1993) developed a program of land-based exercises to stimulate normal balanced growth to offset the specific incomplete development that is the result of unbalanced growth caused by the limited body work of competitive swimming training (Astrab *et al.*, 2001; Batalha *et al.*, 2010).

In programs designed to *"improve"* swimmers' performances there is little support for any beneficial transfer from the foreign irrelevant movements of land-based programs to competitive stroke swimming. Breed, Young, and McElroy (2000) found that dry-land strength training improved the dry-land exercises used for training but did not influence the performance of racing starts. It is not surprising that the exercises used for training improved the performance of those exercises. That is exactly what the Specificity Principle would have predicted. Similarly, Basgier, Karkoska, and Grandjean (2004) found that two forms of explosive training improved standard jumping tests; evidence of the Specificity Principle again. The fact that swimmers were used as subjects does not count for anything about the value of those land-based exercises. No measures of in-water performances were obtained. It is illogical to conclude that swimmers' swimming performances would improve from performing the tested explosive training. The same result would have been likely if cyclists or badminton players were used as subjects. They too would likely have improved in the jumping tests with no reason to infer any transfer of benefits to their respective sports. Further, Wright, Brammer, and Stager (2009) recorded that swimmers training on a *Power Rack* improved performances on the *Power Rack*. Despite the *Power Rack* training being in the water, there still is no logical ground for inferring that the *Rack*-training improvements would transfer to free-swimming. There is no evidence to support such an assertion.

Sokolovas (2000) surveyed United States National Team members on a number of factors. He found that auxiliary training (dry-land work) was likely to be detrimental to performance improvement in female sprinters and is unrelated to improvement in distance swimmers and male sprinters. Its value has to be questioned critically. Crowe *et al.* (1999) found that muscular strength was unrelated to sprint-swimming performance. Costill et al. (1983) concluded that strength developed in the water is more useful for the development of age-group swimmers than dry-land training. Dry-land training has the potential to negatively affect swimming performance because of disruptive transfers to swimming technique as well as not being associated with performance improvements. Bulgakova, Vorontsov, and Fomichenko (1987) assessed the value of weight training on age-group swimmer performances. There was no benefit revealed. It would seem that strength developed in the water is more useful in the swimming development of age-group swimmers. Tanaka *et al.* (1993) concluded that the technique of sprinting should be a primary focus of training. Coaches should not believe that extensive strength and power work on land will develop maximum sprinting potential. It is only when the physical attributes are applied correctly to produce the greatest propelling efficiency that best performances will result. Coaches should emphasize using physical attributes in the technically best manner possible by swimming powerfully at sprinting speed. Costill (1998) has resolutely stood by the results obtained by his associates and students often in conjunction with him that land-training does not positively affect swimming performances [particularly sprint swimming where strength is supposed to be a major attribute]. His recommendation for improving swimming power/explosiveness is to swim as fast as possible and let the increased magnitude of resistance be the load against which swimmers work in very sport-specific circumstances.

Carl *et al.* (2010) correlated dry-land strength measurements and in-water force generation. Bench-press strength was moderately correlated with both in-water force measurements. In addition, leg-press strength was significantly correlated with 25-yard swim time. For all measurements taken, males demonstrated a higher level of correlation than females. Since a 25-yard swim is not a competitive event, it would be wrong to conclude that the moderate strength relationships demonstrated still existed for longer distances. Previous research reported above showed that as the length of swimming tasks increases, correlations with land-strength measures decrease quickly and notably.

Hus, Hsu, and Hsieh (1997) published one of the few research accounts that showed a benefit from strength training for swimming performance. They also focused only on 50-m sprint time which is a competitive distance. It is not possible to determine if this finding is a false positive although its implication is contrary to the majority of acceptably controlled and designed research studies. Assuming that very short sprint performances (≤50 meters) are related to land-strength there may be some value in considering strength training for individuals who wish to compete in those events. However, strength training for distances beyond *"power"* sprint-races still is a dubious procedure, particularly if it is entertained for very long periods of time (e.g., as a ritual part of a season's program). Until many more studies emerge supporting the value of land-training for swimming performances, even for only sprint events, it is a stronger argument to agree with the Specificity Principle and conclude that land-work will not transfer to any positive degree to swimming performances.

The examples described in this section are but a sample of the many more common phenomena in traditional swimming training that violate the Specificity Principle. The overwhelming evidence supports the discrete nature of all human movements is sufficient to first apply the criteria for judging the specificity of non-swimming exercises to determine if or if not they should be adopted as a valuable swimming experience. Further, within the water, if exercises and training sets are supposed to benefit competitive swimming performances also apply the same criteria to determine such activities' value. USRPT as much as is practically possible, adheres to the Specificity Principle. It is not hard to see how USRPT content differs so much from the content of traditional training. USRPT program content is deemed to be *relevant* for positively influencing competitive performances. The traditional training content that does not conform to the specificity-determination criteria is best described as *irrelevant* training with the main influence being negative on swimmers' innate performance potential.

The assertion that swimming does not benefit from non-swimming activities is largely supported by the fact that most auxiliary activities are drastically different to competitive swimming techniques and intensities. It is worthwhile to consider other activities that are more closely allied and see if they fare better by gaining some semblance of transfer. For the *"comparable"* activities of cycling and running, which predominantly use the muscles of the lower limbs, it was found that cycling training produced gains in cycling performance that are not as readily noticeable while running (Pechar *et al.*, 1974). The load is carried differently by the muscles of the lower limbs when running and cycling. Under most circumstances the gastrocnemius (calf) muscle is used to a greater extent than the quadriceps group in running than in cycling. The reverse is true for cycling. However, there are some examples of benefits transferring from one form of exercise to another. Hickson, Rosenkoetter, and Brown (1980) reported using heavy resistance training on the quadriceps, which along with the gluteal muscles are the prime-mover muscles of cycling. After 10 weeks, strength had increased by 38 percent. Time-to-exhaustion had improved by 47 percent on a bicycle test but by only one quarter as much on a treadmill running test. VO2max improved only 4 percent. This suggests that strength training may increase endurance capacity even without an accompanying increase in VO2max. This *"transfer"* was qualified by indicating that the greater the concentration on the muscle group and action, the more likely this effect is to occur. One way of accounting for this phenomenon is that after strength training the same load is supported by fewer anaerobic muscle fibers because a person works at a lower percentage of maximum strength. Consequently, endurance is increased because it takes a longer time to exhaust all the strengthened fibers. Even though transfer of training effects was evidenced, the amount was trivial and would have been achieved much faster and more efficiently by specific training. The consideration of what and why any transfer occurs between activities is not as simple as usually thought.

Implications of Specificity for Coaching

There are several practical implications surrounding the Specificity Principle for coaching swimming. It is clear that the muscle groups involved in swimming should be those that are trained. While there may be some initial value in improving the size, strength, or endurance of muscles with non-specific training, ultimately the muscles must be engaged in the exact movements of the sport. Commercial resistance machines, in which movements such as the leg press and shoulder press are used to enhance the size and strength of certain muscle groups, have their greatest benefits in rehabilitation and bodybuilding. They have little specific value for sporting movements. Total-body free-weights, such as squats, cleans, and snatches, require balance and coordination. Other activities, such as medicine ball work and plyometric rebounding, also involve large groups of muscles in complicated actions. One could think that integrated actions that are required by such activities may have greater value as a method of training for swimming than do isolated simple exercises. It should be remembered that there probably is no other activity that remotely resembles swimming.

Particular care must be taken when using devices that attempt to duplicate the movement patterns of swimming. Interference with technique can occur when the movements are similar but not identical. For example, the Biokinetic swim bench uses isokinetic movements to overload the muscle groups throughout the range of movements involved in the swimming stroke. However, it does not allow *exact* duplication of the stroke. The pattern of movement in the water is different from that on the bench, and the contraction modes are dissimilar. These are two features that have been highlighted above as being critical for determining the value of training activities in terms of specificity and the potential to transfer any benefits to the sport. A coach needs to be very careful that this type of training does not disrupt a swimmer's technique. As was shown above, such activities are too remote in likeness to swimming to trust any positive transfer to competitive swimming strokes at race-pace. At best they have no transfer value (as was found with drag-suits – Dragunas, Dickey, and Nolte (2012)) and at worst they create competing movement patterns or contaminate existing movement patterns that cause propelling-efficiency to decrease.

The proper administration of a USRPT training segment is to have swimmers incur neural fatigue (technique changes and no matter how hard the swimmer tries slower than race-pace swimming ensues) and terminate the set being performed. That procedure minimizes the performance of distorted techniques. The overwhelming proportion of USRPT swimming strokes should be with correct technique[13] at race-pace. An important feature of USRPT is to amass a huge amount of correct-stroke experiences and to greatly limit the number of incorrect strokes swum. It is hypothesized that if correct-technique (good) swimming is very strongly conditioned in a psychological sense, then when fatigue is reached in races, correct swimming will continue because the competing poor swimming techniques will be too weak to be elicited. If poor techniques developed from large amounts of fatigued/slow-swimming are very strongly conditioned (an artifact of traditional training), then it will be easier for the body to unconsciously switch to the poor forms of swimming on the fatigue cue. Few coaches have considered what swimmers are learning when they continue to practice with poor form and performance standards. What results from that is poor swimming is associated with fatigue (in a Pavlovian conditioning sense) and propelling-efficiency in races will decrease with the advent of fatigue sensations. A USRPT dictum is: Swim only race-pace (or slightly better when it is warranted) and restrict as much as possible non-race-pace swimming even for the dubious processes of warming-up or cooling-down[14] in the pool.

One of the most obvious signs of a lack of specificity in training is soreness experienced in muscles after unaccustomed exercise. For example, a swimmer is likely to wake with muscle

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[13] The main thrust of USRPT is the development of correct techniques resulting from an intense coaching emphasis on swimming well and developing techniques in a pedagogical manner. Unfortunately, many coaches who employ USRPT purely focus on the physical conditioning aspect, which normally should happen as a by-product of implementing technique changes while swimming at race-pace. Without the technique instruction and continual development as the primary element of USRPT, swimmers will only gain slightly from simple conditioning because it is the least influential factor in determining swimming success.

[14] When a swimmer enters the water, the core temperature and skin temperatures fall. Depending upon the amount and intensity of training, the core temperature rises, sometimes to levels higher than originally existed in ambient air. Stopping and standing in the water cools the swimmer down quite quickly because water is a very good conductor of heat. Consequently, warming-up by swimming is more likely to be a procedure that recaptures part of the initial cooling that occurred upon entering the water. Warming/cooling-down activities at the end of practice are of little value because it is more than likely the swimmer is already cooler than the temperature that will be stimulated by ambient air when the swimmer leaves the pool to go home. Both activities are a waste of time. Pool time would be better spent by pursuing more USRPT activities.

soreness the morning after trying a new exercise program. Even when a swimmer is asked to do more sprint work, the recruitment of fast-twitch fibers, which is uncommon in training, can produce telltale signs of a lack of specific training. Coaches should be aware of signs of soreness that result from competitive or excessive efforts. What signs do occur indicate that training has not been comprehensive enough to fully prepare athletes for all the activities required in competitions. There are four signs that also indicate non-specific or unrelated training. They are as follows:

- muscular soreness in recovery,
- acute localized fatigue in the activity,
- a subjective appraisal by an athlete that the work being done is harder than usual, and
- a quick occurrence of fatigue.

One of the most uninformed statements made by swimming coaches when a swimmer complains of soreness or stiffness in muscles some time after a hard effort or unusual exercise is to attribute the sensation to lactic acid still residing in those muscles. After a demanding event that develops lactate levels higher than 4 mmol, the lactate is oxidized and removed normally within one-hour or shorter post-race. Rather, the soreness/stiffness is an indication that training has not been inclusive of all relevant factors.

Another alternative that must be considered as an index of non-specific training has to do with training effects and their enduring status. For example, Carlile and Carlile (1961) reported that Australian swimmers trained with weight exercises prior to commencing hard swimming training in preparation for an Olympic Games. During the swimming training, no weight training was performed. After 10 weeks of swimming training that produced overtrained states, thereby attesting to the intensity of the training load, it was found that strength gains that had previously been achieved prior to swimming had regressed back to untrained levels. If the strength gains had been valuable, then the intense swimming training would have at least maintained some of that developed fitness component. This suggests that the level of strength adaptation that had occurred through resistance exercises was unrelated to the sport of swimming. Another negative aspect of strength work in swimming also occurs. The body density increases altering buoyancy resulting in the swimmer sinking lower in the water and increasing resistance. This example raises an intriguing question for coaches. Why train on activities that are not required (stimulated) by the specific sporting activities themselves? The only non-specific activities that should be tolerated should be familiar, low-intensity activities, which facilitate recovery. Thus, another index of specificity exists. When training effects are incurred but are not maintained by the activity, then those effects are generally not specific to the activity.

The challenge presented by the Specificity Principle is to choose training stimuli that have the movement characteristics of the activities involved in a sport. This is very difficult to achieve since only minor alterations from an exact action change the characteristics of the systems that produce the altered action. Such changes are potentially harmful to a well-trained swimmer.

Training increases the skill for an activity at a particular work-intensity. Neuromuscular patterns are established which produce efficient use of existing resources. The major physiological site of specific adaptations is in the muscles. Specificity applies between sports, between events within sports, between precise skills, rates of work, etc. What is trained is what is developed and if the activities of training do not replicate those of competitions, then the value of observed training effects would be greatly decreased. Irrelevant training effects can occur even though they will serve no purpose in a competitive effort.

The Specificity Principle implies that specific training will only achieve desirable training effects that transfer directly to competitive performances. Non-specific/irrelevant activities -- and activities do not have to vary much to become non-specific -- have the potential to interfere with good technique and the competent use of specific fitness. Training activities that do not replicate the physiological and neuromuscular components of a sport have the potential to detract from performance through the phenomenon known as negative transfer (Bompa, 1986).

However, there are cases where non-specific activities do have value in training programs. Very non-specific activities may not load the muscle groups and fibers involved in the sport, and so in unloading the stress, may aid the recovery process and the ultimate training response. Unrelated activities might also provide variety in the sporting environment that could relieve boredom that would result from consistent overuse of specific activities. In using non-specific activities, their volume and intensity should decrease as the period of major or important competitions approaches. The emphasis placed on them should never match that afforded specific training items.

Coaches need to decide the specific and non-specific activities of a sport. Non-specific or near-specific activities have a potential to be harmful. Unrelated activities can be used to assist in recovery and for program variation. The selection of specific training stimuli will determine the effectiveness of sport training programs. Only those activities which have direct positive transfer to competitions are those which should constitute the major portion of a training program.

The Specificity Principle should not be controversial although those willing to exhibit their ignorance of human function attempt to make it so. The Principle is an accounting of natural phenomena, that is, how events occur in the real world. It presents a great difficulty for the generalists who claim training by competent performers on one activity improves performance on another. Those who espouse weight-training for strength as being an avenue for improving competitive swimming performances have to be able to explain and illustrate with facts how a unique set of weight-training movement patterns in brain activity improve a discretely different set of movement representations associated with competitive swimming efforts for their hypothesis of transfer of training effects to be valid. Such hypotheses of the associations between uncorrelated physical phenomena (i.e., the different movement patterns of each activity in the brain) have historically arisen from time to time. It was not that long ago when educators proposed children learn Latin as a means of teaching them to concentrate and gain an *"organization of their thoughts"* that would embellish their understandings and competencies in other subjects.[15] That biomechanical factors involved with swimming a stroke at slower-than-race-pace velocities are so different to those exhibited when swimming at race-pace, and are so represented in distinctly different brain activity patterns, should be sufficient to prove the inappropriateness of such training items for improving swimming-race performances. But yet, swimmers involved in traditional training programs still spend more time on that type of

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[15] Thankfully the folly of this *"learning principle"* has been exposed and this practice is almost extinct. Educational time is supposedly better used, although in many cases the substitution of other subjects and teaching philosophies might have a similar lack of effect and/or educational value.

irrelevant pace-work than on preparing for racing. For any coach that proposes an irrelevant training activity, an adequate answer of known physical functions preferably at the neurological level to the question of "*How does that activity promote the same movement patterns in the brain as those fostered by swimming at race-pace?"* has to be proffered. A failure to answer correctly is a manifestation of ignorance.

The paradox of beginning to learn complex movements, when movement patterns are not established, being influenced by a variety of experiences most likely is associated with cognitive control (i.e., understanding what needs to be done) rather than any change in physical phenomena. It is an accepted fact that upon beginning strength training the initial improvements in strength-exercise performances are associated with the reorganization of existing bodily resources without any observable structural changes. The development is one of increased skill. That supports the strong role of cognitive control over the activities as they are repeated in early learning experiences. Essentially, it is the cognitions that improve the skill of moving that produce the performance changes in beginner-athletes. A somewhat similar process underlies learning-to-swim. Once swimming performances and strength-training performances for that matter have reached the limit of the influence of cognitive control, the nature of performance changes with elements of skill within the complex movement becoming automated, that is, the elements are no longer accompanied by control cognitions. From then on the nature of instructional/coaching should change and movement efficiency/proficiency should become a major instructional thrust as well as limiting practice items to relevant activities that facilitate improvements in movement efficiency. In swimming, improved movement efficiency facilitates both swimming faster and further at a particular velocity. Both outcomes improve competitive performances if the training has been relevant (related to) racing.

To finally make a justification for observing and following the import of the Specificity Principle for competitive swimming, traditional swimming coaches who employ the dominant yardage at slow velocities, rely on irrelevant non-swimming activities (e.g., land-training, drills, the use of detrimental skill-altering swimming equipment, and part-skill practice items) is the swimming equivalent of those who believe(d) the world is/was flat as opposed to those who used sound evidence[16] to propose and follow a different more-specific form of swimming training and development (i.e., USRPT). One case for USRPT as being a preferred training format and structure is that it adheres to the Specificity Principle to a much greater degree than the irrelevant-activity programming of traditional swimming training.

The Specificity Principle cannot be denied. It is a part of the human experience in any endeavor. It warrants uncompromising acceptance to the same level as that afforded Newton's Three Laws. It is time for swimming coaches to cast off the shroud of ignorance and focus swimmers attention on relevant training that maximizes training effects that transfer directly to competitive efforts.

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[16] Nicolaus Copernicus proposed that the earth rotated around the sun but his hypothesis captured the attention of few. Galileo Galilei became devoted to Copernicus' evidence-based proposal and with further observations through his inventions of strong telescopes and mathematics proved the model conclusively only to incur the wrath of the Catholic Church of the day (the then *"traditional theorists"* of the relation of the movement of the sun around the earth). For the rotations to occur, the planets and star needed to be round, a fact that had been revealed more than a century earlier by the westward sailing of Christopher Columbus and finally by Fredinand Magellan's expedition sailing westward finally landing on islands that were known to sailors who had only sailed east.

To close this long exposition of the Specificity Principle, it is worthwhile to reiterate the seven criteria that have to be met for a practice activity to have direct relevance for particular swimming races. Coaches should evaluate the content of their existing programs using the criteria and determine how much is and is not relevant for competitive swimming races. It is recommended that the irrelevant activities be discarded. The criteria for determining specificity are:

i. The posture of the movement.
ii. The locus/path of the movement technique.
iii. The muscles used.
iv. The type of muscle contractions performed.
v. The velocity of movement of the activity.
vi. The resistance magnitude and type.
vii. The opportunity to practice race-thinking or race-technique thinking when training.

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