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LEVELS OF FATIGUE IN SWIMMING

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There are various levels and types of fatigue that occur in swimming practices. It is helpful to understand these so that sound program decisions can be made.

When a set of repetitions of swimming, a particular type of exercise in the weight room, or a session on a swim-bench is planned, each block of exercises attempted is a *training stimulus*. At the completion of the training stimulus experience, the body should have changed in the way the stimulus provoked. In accordance with the Principle of Specificity, specific exercises train specific movements and do not generalize to other activities. How the swimmer reacts to the training stimulus is a *training response*. What results from an exposure to a training stimulus is a *training effect*. The degree of demand of the training stimulus is the level of *training stress* (Rushall & Pyke, 1991).

Training stimuli can be of two classes. First, they can be relevant, that is their effects directly enhance a competitive performance. Second, they are irrelevant, that is, their effects do not contribute to competitive performance enhancements. Irrelevant activities can improve because they have been practiced but if there is no transfer to a competitive performance they are essentially a waste of time.

In some situations, activities that do not appear to be directly relevant for a competitive performance can be of tangential influence on a competitive performance. An example of a remotely relevant activity would be performing strengthening activities in injury rehabilitation. However, most activities that coaches think are beneficial for a swimmer are not. No matter how many truck tires are thrown, how much spinning is done, or how much slow swimming is performed, there is no neurological, biomechanical, or physiological reason/evidence to substantiate beliefs of benefit.

As has been argued at length elsewhere (Rushall, 2013a; Rushall & Pyke, 1991), in a complex movement where technique is the major determinant of swimming achievement (Sokolovas, 2000), performing the activity at the intensity, velocity, and form required for those two factors to be executed exactly, is essentially the only activity that leads to performance enhancement from specific training effects. The training stimulus that replicates the technique and energy requirments of a particular race distance, stroke, and performance level is embraced by the USRPT format. The value of USRPT is that it offers the opportunity to experience the greatest volume of race-specific training stimuli.

Fatigue level 1. In a race-specific ultra-short training stimulus, the body is disrupted in a very specific way. Repetitions are completed under the ultra-short format which generally involves a high number of repetitions (a minimum of 20) completed at a consistent performance level (at the velocity for a specific-race pace) with short rests (a maximum of 20 seconds). Eventually, the stress of the training stimulus takes its toll and one or more aspects of the exercise fatigues and performance falls below the desired standard. In USRPT a brief rest equal to the duration of a repetition (work plus rest) is allowed and the performance is tested again by resuming in the set of repetitions of the training stimulus. Often a few more repetitions are successful and then another failure to perform at the desired standard occurs. A further one-repetition rest is allowed. If that rest is insufficient to promote adequate recovery of the performance standard on the next repetition, participation in the set is terminated. A feature that differentiates USRPT from traditional training is that a USRPT training stimulus has to be sufficiently challenging that the athlete cannot complete the total set. Two contiguous "failures" should occur before the programmed maximum number of repetitions. The impossibility of set completion guarantees each swimmer will experience a maximum, specific training effect.

What has happened in the above scenario is that the specific effects of the training stimulus have been sufficient to promote specific fatigue that prevents further execution of the training stimulus elements at a particular performance level. For specific movements to benefit from training, they only need to fail performing a standard in a relevant training stimulus. A swimmer targeting any pool-swimming event does not need to work any harder. The ultra-short training format guarantees the maximum work in response to a specific stimulus at a specific performance standard, that is, it is race-specific and is not accompanied by high levels of exhaustion. The most valuable work in swimming training does not need to be extremely exhausting.

After sufficient recovery, often half a day or at most one day, the body overcompensates in the recovery of the features required in the fatiguing training stimulus so that the next attempt at the same or a similar training stimulus performance is enhanced. In USRPT, performance improvements resulting from overcompensation usually are more repetitions being completed before the first failure and/or the total number of successful repetitions (total specific "yardage") exceeds that achieved previously. Those positive outcomes resulting from specific-performance fatigue and the overcompensation it stimulates, indicates the occurrence of performance improvements at race-pace which should be interpreted as the swimmer is better equipped after the experience to improve performance in a race than before the training stimulus and effect occurred.

The experience of a training stimulus and stimulus standard failure that is not devastatingly exhausting is the *first level of fatigue* and all that is needed to improve a complex-movement performance such as a specific swimming race. USRPT provides those stimuli and consistently yields training effects for as many races as can be accommodated in a swimmer's program.

Fatigue level 2. Traditional swimming programs provide sets of repetitions all of which must be completed. The standard of swimming between repetitions often is quite variable. Usually, sets are not race-specific. When a task comprises repetitions of the same distance (e.g., 8 x 200 m FS on 3 minutes), swimmers start with a number of repetitions at an "acceptable standard". However, the latter repetitions often display a deterioration in response quality.

What happens in a traditional set is that somewhere through the set a first slowing in repetition performance occurs. If the set was stopped then, it is likely that a specific training effect could be generated (although mostly not specific for racing). However, as further repetitions are completed, the body is forced to use additional resources in an attempt to cope with the challenge of completing the remaining repetitions as excessive fatigue mounts. The training response changes from initially being specific to being general and non-specific. The general reaction stems from the attempt to complete the number of repetitions with little regard for performance standard or the quality of the skill elements that underlie the latter part of the response. The developed generality of coping responses is superimposed on and masks any specific effects resulting in little to no improvement in a potential race performance. The repeated exposure to general highly-fatiguing training stimuli in a practice session gradually develops excessive exhaustion that usually takes from 36 to 48 hours for recovery. Repeated exhausting training sessions accumulate negative effects and produce an *overtrained state* which is synonymous with Selye's *Stage of Exhaustion* (Selye, 1950). Overtrained states usually take more than one week of respite from exhausting training stimuli for recovery.

Coaches who prescribe consistently "hard" training sessions which also demand high volumes of swimming generally have their swimmers continually in states of exhaustion most moving toward overtraining. Not only do performances worsen as training proceeds, particularly with sprinters, but swimmers' attitudes, character, and motivation for training decrease, and the susceptibility to illnesses increases. It is not hard to discern when swimmers are exhausted. They do not swim well, training responses diminish, their psychology becomes negative and they suffer a variety of over-stress symptoms (e.g., uticaria, sore throats, rhinitis, colds, muscle and joint soreness, swimming-related injuries, etc.). A verifying event that reinforces the diagnosis of overtraining or chronic exhaustion occurs after a swimmer is out of the water for several days to recover his/her health. During the respite, the swimmer is commonly feared to have "de-trained", but when they return they swim better than before the illness. The illness has allowed the swimmer to recover and recapture some potential for swimming better than when in the state of being beaten down by repeated exposures to exhausting training. The individual response to hard training programs is quite varied and usually a few "strong" individuals can tolerate the fatiguing exposures better than others.

The result of traditional training programs is that largely they train swimmers to train, not to race. Indeed physiological measures taken during hard training show changes in the measured capacities but those changes are unrelated to eventual tapered race performances (Anderson et al., 2003). If a swimmer trains fully with a coach and in-season performances do not show much if any improvement and then go through a taper and still competition improvements are not registered it is reasonable to conclude that all the training that was completed was irrelevant for improving racing.

This level of fatigue has few benefits and many perils for swimmers. The training responses are general which prevents the development of race-specific propelling efficiencies and the energizing capacities that support them. General less-than-exact swimming experiences offer no opportunity to improve or refine the qualities that are essential for improving specific competitive performances. It should not be surprising that high-intensity training (USRPT) yields better training effects than traditional training in many dimensions (Rushall, 2013b).

Fatigue level 3. The third level of fatigue has characteristics similar to the second level except that the sources of exhaustion are more varied and decidedly irrelevant for swimming performance enhancement. The sources of exhaustion actually interfere with a considerable amount of opportunities for any tangential or possible benefit for competitive performances. Usually, large amounts of land exercising in any number of modalities and formats are performed. An athlete's application to the land-training is exhausting and frequent.

The land programs are justified misleadingly by comments such as *"I will get them ready to swim fast, you* [the coach] *show them how"*; *"the program I have designed is specifically for swimming"* [when no land-training could have any specific positive carryover to competitive performances]; *"by working them very hard I will teach them mental toughness"* [just like football players where both the bad and good teams do considerable off-the-field training for little to no benefit (Harney et al., 2001; Miller et al., 1999)]. An objective interpretation of out-of-the-pool training is that activities make swimmers better out-of-the-pool trainers but there is no transfer of beneficial specific land-training effects to competitive performances.

Land-training for experienced competitive swimmers is irrelevant for competitive swimming performances (Bulgakova, Vorontsov, & Fomichenko, 1987; Breed, Young, & McElroy, 2000; Costill et al., 1983; Crowe et al., 1999; Tanaka et al., 1993). If fatigue from land-training is carried into swimming practices it is likely to be detrimental to swimmers' practice performances. Effort levels will be reduced, techniques will be compromised, the experience of swimming training will be negatively affected, and the volume of swimming training will be reduced in every affected training session. Despite the negative association between land work and pool work, coaches and swimmers "buy" the land-training drivel and false claims and relate any coincidental improvements to it and ignore its influence when analyzing failures.

The state of continually being in some form of fatigue is particularly worrisome. General fatigue halts the possibility of refining specific movement patterns, that is, there is no possibility of improvement in propelling efficiency for any stroke. When attempting to cope with an exercise stress a variety of resources, both energetic and topographic, are sampled very frequently producing a functional outcome without movement precision. Attempts to change segments of techniques would be futile because fatigue prevents that possibility. When swimmers are continually fatigued over any length of time, performance improvements cannot occur. That is despite the coach believing that there is something "good" happening within the swimmer when empirically only bad things are evident.

Hard training in the pool and gymnasium/weight-room is a recipe for disappointment. So much time is devoted to irrelevant activities that performance improvements are relatively rare. It is not uncommon to have swimmers come from moderate land-training programs in high school or club programs to have the land work increased markedly in college. A considerable number of athletic directors require swimming teams to use the weight-training facilities under the direction of a conditioning/strength coach who has little appreciation for elite swimming needs. It is common for college swimmers (particularly women) to not improve on their best times recorded before college. Failures to improve over four years or from year to year in college is largely attributable to hard fatiguing work on many activities that are irrelevant for competitive swimming enhancement.

The most common indications of irrelevant training are complaints of post-exercise soreness, painful swimming, and the development of injuries. If strength exercises are done on machines that allow a few muscle groups to be worked to extremes very often muscle fibers are damaged. Those subtle pre-cursors of obvious injury are carried into other activities where over-use or heavy fatigue stresses cause them to become serious injuries.

McArdle, Katch, and Katch (2004) clearly delineated the limitations and specificity of strength training;

> "*An isometrically trained muscle shows greatest strength improvement when measured isometrically, whereas a dynamically trained muscle tests best when evaluated in resistance activities requiring the movement. Furthermore, isometric strength developed at or near one joint angle does not readily transfer to other angles or body positions that demand use of the same muscles. . . In dynamic exercise, muscles trained through movement over a limited ROM* [Range of Movement] *show the greatest strength improvement when measured in that ROM. . . Even a body-position specificity exists; muscular strength of ankle plantar and*

> *dorsiflexors developed in the standing position with concentric and eccentric muscle actions showed no transfer when evaluating the same muscles' strength in the supine position. . . Resistance training specificity makes sense because strength improvement blends adaptations in two factors: (1) the muscle fiber itself and (2) the neural organization and excitability of motor units that power discrete patterns of voluntary movement. . .*
>
> *Likewise, a muscle's maximal force output depends on neural factors that effectively recruit and synchronize firing of motor units, not just local factors such as muscle fiber type and cross-sectional area. . .* [Research] *findings provide strong evidence that resistance training per se does not induce all-inclusive (general) adaptations in muscle structure and function. Rather, a muscle's contractile properties (maximal force, velocity of shortening, rate of tension development) improve in a manner highly specific in the muscle action used in training. . . strengthening muscles for a specific athletic or occupational activity . . . demands more than just identifying and overloading the muscles used in the movement. It requires training specifically in the important movements that necessitate improved strength*" (pp. 520-521).

Of particular relevance to specific training for swimming training, is their final conclusion:

> "*To improve a specific physical performance through resistance training, one must train the muscle(s) in movements that mimic the movement requiring force-capacity improvement, with specific consideration for force, velocity, and power requirements*" (p. 521).

Strength exercises using very heavy resistances and high levels of effort damage muscles for as much as 48 hours (Dolezal et al., 2000). Heavy exercise produces muscle damage in the form of "*minute tears or damage to contractile components with the accompanying release of creatine kinase (CK), myoglobin (Mb), and troponin I, the muscle-specific marker of muscle fiber damage*" (McArdle, Katch, & Katch, pp. 540). When coupled with extreme stretching and ranges of movement, tearing of portions of the muscle's connective tissue harness also occurs (p. 540).

When exercises in both training environments are performed to fatigue, each negatively influences training responses in the other environment. Detrimental fatigue from mostly irrelevant activities thwarts the development of improved aspects of competitive performance factors at pool-training. Too many examples exist where world-class swimmers perform magnificently at a world championship and follow that with as much as a year of increasing the amount of land-training undertaken as a way of preparing for the next major meet, such as an Olympic Games. In pre-Games hype, the ridiculous irrelevant training activities performed on land make good television reports that are positively attributed. At the ensuing Games, performances very often are worse than 12 months earlier on the world stage. The obvious feature of the increased emphasis on and introduction of irrelevant and dangerous activities is disregarded as the cause of performance decline. That is disconcerting. The irrelevant activities are promoted as the reasons for expected improvements. But when the improvements do not occur and performances regress in mostly all events in which the swimmer competes, one would think the new activities, heightened level and frequencies of exhaustion in the land-exercises and other in-pool activities, being features not existing prior to the previous world championships would seem to be the cause of degraded performances. However, in a psychological sense, if one repeats the justification of doing more land-training harder than before as being so beneficial, it is difficult to question the repeated erroneous belief. A willing audience unquestioningly accepts what is seen and heard on TV and follows by aping the activity. The group of unimproved swimmers grows.

The features that separate level 3 fatigue from level 2 fatigue is the scope and amount of irrelevant training that produces general non-specific-for-swimming fatigue and the prevention of improvements that fatigue introduces into pool-swimming. An occasional champion with exceptional physical-stress tolerance capacities will survive and record good times. Such a swimmer achieves despite the coaching received. Because a swimmer cannot endure an unending set of stressful coaching practices does not mean they cannot be a champion.

Havriluk (2012) investigated the effects of a hard swimming program on swimmers' hand-force production. Although one cannot tell if the evaluated program was of the ilk that would produce fatigue level 2 or 3, it still has implications for evaluating the value or lack thereof of programs that are depicted as having *"a substantial workload"*. Comparisons were made on swimmers' (N = 9) ability to generate freestyle hand forces before an 8-month training period (baseline - a relatively untrained state), in the middle of the experience when training stress was likely to be highest, and then at the end after a taper. All swimmers had reduced hand-force production in the middle of the training period. It is likely that much training was completed in a disrupted state that prevented force production even equal to baseline. The justification for having swimmers perform for months in a depressed performance state is hard to imagine. As the workload leveled-off and a taper was experienced at the end of the investigation, only five on the nine swimmers recovered to force-production levels that exceeded baseline amounts. Four swimmers trained for eight months to be beaten down to a point where they could not recover sufficiently to match the pre-investigation "untrained" state. Eight months of their lives were wasted.

Of the four swimmers who did not recover fully despite a taper, three recorded the greatest loss in force production at the middle of the study. The fourth member also had a low depressed level of production that was close to another swimmer's recording but that individual responded in the latter part of training to marginally improve on baseline force production. Although there were few subjects in this study, it is interesting that of the five swimmers with the greatest loss of force development, only one responded to improve on baseline standards.

The single index of force generation on the hands showed a number of features;

i. Swimmers who are very much fatigued over a long period of training are likely to have difficulty recovering to untrained force-production (performance) levels despite a taper.
ii. Only swimmers who tolerate excessive training stresses relatively well (i.e., their performances are only moderately depressed) recover and show some, although mostly small, training effects after eight months of exposure.
iii. The measurement of force production on the hands could be used as an index of training stress reaction with excessive depressions prompting that an alteration in load needed to be instituted for affected swimmers.
iv. Since force production on the hands is moderately correlated with swimming performances, the pattern and level of competitive performances during the training period also would "send a message to the coach" that training-load adjustments were needed.

The most significant implication of Havriluk's investigation is that a moderate amount of depressed force-production/performance is tolerable in traditional training programs, but a large amount dooms a swimmer to failure even after a taper. Within the context of this discussion, why should swimmers be subjected to such a risky business? USRPT does not expose swimmers to such risks because performance depression of any magnitude prompts rest and recovery that facilitates performance improvements at practice and in competitions.

Closure

When a human participates in an activity that requires precision of movement and the dispersal of energy to develop top performances, it is insufficient to apply the general edict that the greater the amount of and the harder the work, the better. In swimming, precision (technique) is the major determinant of success and thus the development of skills and how they are energized specifically is a sure-fire approach to developing athletes' potential. The addition of mental skills training is also in the equation leading to success but that has not been part of this presentation.

1. The first level of fatigue is the specific approach to developing the skills required to compete in various swimming races as well as the specific energy to power the associated skills. The fatigue that is required to produce a training effect[1] is specific and a partition of all the energy that resides in a swimmer. Specific fatigue affects performance only and requires relatively quick recovery before the activity is attempted again at a similar or improved level.

2. The second level of fatigue is within the activity of swimming but extends the skills to be outside those required for competitive races. Thus, the concepts of relevant and irrelevant training emerge as to whether a training program provides experiences that improve competitive performances as well as non-competitive performances. Each relevant and irrelevant activity demands energy and patterning in the brain. When much energy is expended beyond the level that produces training effects, the skills and energy expand into the general and mostly irrelevant activity area. While in this level, the vast majority of work is in swimming but it is deficient in two ways.

    - The skills learned and practiced are beyond those which are really required in competitive situations. The prospects of confusion in the athlete, of dominance of irrelevant over relevant skills, and the excessive consumption of time in irrelevant activities are high in this category of swimming coaching. [The consumption of time possibly restricts the amount of time that can be used for the development of relevant skills.]
    - The level of fatigue that results from "hard" and "demanding" programs moves from specific to general in effects. Not only is the energy consumed excessive but the resources within the body (e.g., glycogen) are diminished and prevent any effective relevant skill development and specific training effects.

    This model promotes excessive work in both relevant competitive and irrelevant swimming activities. Science does not support the scope of this model.

3. The third level of fatigue includes the second level but extends the scope of the activities to swimming and non-swimming pursuits. Quite often, the non-swimming activities and their excessive fatigue impinges on what can be done in the pool to the extent that any swimming activities very often cannot yield training effects, whether they be relevant or irrelevant.

    This model promotes excessive work in all prescribed activities and depresses swimming performances to the extent that with even reasonable recovery opportunities

[1] In this context, training effects are necessary to elevate the provision of energy for the skills (i.e., each of all competitive events) to a level that maximizes the availability of that energy when a maximum performance is attempted.

performances remain lower that previously recorded. Science does not support the scope of this model.

Fatigue levels 2 and 3 are justified by dogma and coaches' self-justification. Occasionally, some unique swimmers survive these models and perform exceptionally well despite the coaching received. Unfortunately, those few individuals serve as the basis of generalization while the "failures" are disregarded. If a coach claims coaching success because of the performances of one or a few athletes in his/her squad, then equally that coach is responsible for those swimmers who are unsuccessful. But, that is not within the current culture of competitive swimming. "Great swimmers make great coaches" is still the accepted standard.

Many competitive swimmers can be served better and still be champions if they are consistently exposed to the Fatigue Level 1 model.

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