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FATIGUE IN SWIMMING: THE GOOD, THE BAD, AND THE UGLY

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This essay describes and compares the types/levels of fatigue that are developed in swimmers who train under the Ultra-short Race-pace Training format (USRPT) and two forms of traditional training. It suggests how coaches can determine the level of fatigue that has been developed in swimmers in a specific format of a training program. By knowing the behaviors and characteristics of fatigue levels it should be possible to better individualize a program's offerings (Rushall & Pyke, 1991).

The Good – Training Effects

The stimulus for improving sporting performances is the repetitive exposure to specific forms and quality of exercise stress. Any behavior or adaptation needs multiple exposures to stimuli associated with fostering desired changes in athletes. The level (quality) of the exposure should be such that an athlete repeats designed performances until the performance declines and cannot be recovered, that is, there is a performance failure. That defining moment indicates a particular quality of performance cannot be sustained. The inability to maintain a performance standard very often is accompanied by a detrimental alteration in technique. Their occurrence verifies that a training overload has been achieved. When performance standard and technique decline together, attempts to perform the related task should cease because no more specific benefits are possible.

USRPT maximizes the amount of race-relevant swimming and minimizes irrelevant swimming. Sets are established for specific races with no more than 20-second rest intervals mostly covering distances from 25-75 m/y aiming for a high number of repetitions. All repetitions are to be completed at race-pace. When one trial is slower than the target repetition time the swimmer does not swim the next repetition but rests and recovers. Then the set is re-joined. Further failures are followed by a rest in the following repetition until two failures occur in a row, that is, the next repetition after a rest is also a failure. Two failures indicate that sufficient performance depression has occurred and the training stimulus should cease. The swimmer is sufficiently fatigued to yield the largest benefit possible from the training item. If other swimmers are continuing with the set, the fatigued swimmer participates in active-recovery until the next training stimulus commences for all swimmers. The conduct of sets of a high number of repetitions in this manner guarantees that swimmers experience specific exercise fatigue which is a sufficient stimulus to provoke learning of and adaptation to the specific stimulus (the training set at race-pace). The swimmer does not experience undifferentiated excessive general fatigue which would happen if the swimmer were directed to continue swimming with worsening performance and mounting physical exhaustion. With this criterion to cease participation in a set, USRPT self-regulates against exhaustion.

In USRPT, at the time of the first failure in a race-pace set, it is appropriate to halt the training stimulus by missing the next repetition so that the athlete sub-consciously reorganizes natural phenomena to be better prepared to accommodate the same stimulus when presented again after the short recovery time in the missed repetition. When failure is experienced and specific reorganization is allowed to happen, which results in further but limited quality performances, the point of full benefit from the set of repetitions, has still not been reached. It is only when a rested-repetition is insufficient to make the next attempt successful that the training stimulus should be abandoned. That is the time to begin full recovery from the stimulus. The amount of recovery after terminating a training stimulus usually is more than the amount of performance reduction in the interval set that is, a training stimulus prompts the body to overcompensate for the experience. The excess is called a *"training effect"* and sometimes *"overcompensation"*. If a training effect is experienced in USRPT, when compared to the previous set the next attempt at the same USRPT set should be improved in total race-pace yardage completed and/or the number of repetitions completed before the first failure. That is the theoretical basis of the neuromuscular organization and brain patterning that is the hallmark of USRPT (Rushall & Pyke, 1991; Rushall, 2003).

The rules for failure, within-set recovery, and further failures and/or recovery are great strengths of USRPT. When swimmers are tiring, they are motivated to keep swimming at an appropriate velocity that is race-specific. This teaches them to cope with fatigue and to concentrate on holding a particular race-pace, a situation that arises in a race. Seldom in traditional training is that race-specific experience provided. With USRPT, it occurs in every set at every practice. It develops swimmer determination to race well in the face of fatigue.

USRPT is driven by performance failures and opportunities to improve and guards against increases in lactate or bodily fluids' acidity and the depreciation of glycogen stores[1]. Learning race-pace specific techniques is an essential feature of swimming training at race-pace and it occurs in concert with improvements in the energy supply for specific events (Rushall, 2013a). It is important to maintain an appropriate physical environment within a swimmer's body so that learning (technique improvement) is accommodated while training effects are sought. If acidity rises above a particular level and the supply of glycogen drops below another particular level, learning in skills and movement efficiency will be interfered with or cease, rendering any further physical stimulation a virtual waste of time.

When experiences in the USRPT format halt work because of the onset of unrecoverable performance declines, the level of stress experienced by a swimmer is self-regulated and avoids an athlete becoming exhausted. Swimmer exhaustion occurs when glycogen levels drop considerably and lactate measures climb steadily and usually do not decline in the set. As is indicated below, those symptoms result from excessive work of a poor standard. USRPT work does not allow those factors to develop. If they did, then it would be impossible for one or at the most a few race-pace repetitions to be completed. The performance criterion in any USRPT interval set is a factor that can be determined by the athlete/coach. Recovery from USRPT

[1] Rises in acidity around the nerve axons and synapses interferes with the exquisite conductance of impulses in a pattern that is appropriate for a particular movement. Interference along the neural pathways from the brain to the muscles produces a breakdown in skill level. Glycogen energizes nerve conductance and if it falls below a particular level it will no longer be possible to conduct impulses of a high intensity which, in turn, reduces the forces that can be created. Lowered glycogen stores also thwart learning to a significant degree. For the coach, this means that when a swimmer's technique starts to "fall apart" and the velocity of swimming slows, fatigue has reached a point where no further exercise of that type is of any value. A common manifestation of the glycogen-related substances relationship and effect is in diabetic patients who display memory and learning/adapting deficits.

training stimulus occurs in a very short time, possibly as little as four hours if a nutritious meal (including carbohydrates and protein) and needed rest are allowed. The quick recovery to gain a training effect is one reason why some USRPT swimmers have three sessions per day in the water. The duration of such sessions is shorter than the common pool-availability determined two-hours, and the amount of swimming completed is governed by the readiness of the swimmer to complete criterion-based repetitions. In USRPT, swimmers complete the maximum amount of high-quality/intensity swimming of which they are capable each day. The self-regulation factor prevents any swimmer becoming too exhausted to not perform at or close to a personal best level in frequent competitions. Departures from personal best levels often are mediated by psychological factors rather than training "staleness" or excessive fatigue. USRPT swimmers should be able to perform at high levels at any time of the year. Tapering is unwarranted when fast competition times are sought (Rushall, 2013b).

The avoidance of excessive detrimental fatigue is a major feature that differentiates USRPT from traditional swimming training. Exhaustion is frowned upon in USRPT, but often celebrated in traditional "hard" training. USRPT provides the greatest amount of race-pace work because short work and rest intervals facilitate completing more work than longer interval structures.

Stegeman (1981) related the following which contradicts the common structure of traditional training (particularly lactate-tolerance training sets).

> "*The placement of pauses during work that exceeds the threshold for prolonged work is important. Since the course of recovery proceeds exponentially, that is, the first seconds of the pause are more effective for recovery than the latter portion, it is more appropriate to insert many short pauses than one long pause in interval training. Lactic acid recovers very quickly in a short period of time. Longer time periods do not produce much added benefit. Thus, for prescribing training stimuli of an interval nature, the athlete should be subjected to a certain level of discomfort through fatigue, provided with recovery, and the cycle repeated so that work volume, intensity, and performance consistency are maximized. This is why interval training is so effective for developing anaerobic capacities.*"

It is the ultra-short interval work that maximizes the development of race-pace techniques and their energizing bases (Astrand et al., 1960; Astrand & Rodahl, 1977; Christensen, 1962; Christensen, Hedman, & Saltin, 1960). USRPT is more effective for developing specific fitness, techniques, and specific-training volumes than any form of traditional swimming training (Rushall, 2013c). Stopping a training set when a training stimulus has occurred, that is both performance and technique have declined, is USRPT's secret to preventing devastating exhaustion in swimmers. If the rules for USRPT are followed, swimmers should never enter the Stage of Exhaustion (Selye, 1950), commonly termed overtraining.

The Bad – Traditional Pool Training

Traditional training can be categorized into two types. The first involves a lot of swimming where demanding sets are completed in exhausted states often in two training sessions a day for five or six days per week. The performance levels at practices of this training-dominated model are usually less than race-pace and within a set demonstrate a performance decline in the latter repetitions. Too much pool training can exceed the stress-tolerance capacity of most swimmers. There are some outlier individuals who can handle what seems to be an inordinate amount of "swimming work" and they often go on to have successful careers.

Excessive traditional-training produces very frequent experiences of exhaustion that are far beyond that of a training stimulus. The exhaustion has as two markers; a reduction in stored glycogen levels and the repetitive experience of high levels of lactate (lactic acid). Both phenomena prevent improving propelling-efficiency through learning better techniques and also depreciate general measures of strength in the swimmer. In particular, sprinters are significantly affected by excessive training and only have the opportunity to recover their sprinting abilities/strength through an appropriate taper. Having been in this condition and after a taper, performance improvements are not guaranteed.

When glycogen levels are lowered, the performance potential of a swimmer is lowered even further. Low glycogen levels are a state where there is insufficient fuel for desirable competitive performances. So, not only do low glycogen levels inhibit learning techniques they prevent the swimmer from completing volumes of credible swimming. To overcome this undesirable state, which often takes in excess of 48 hours for recuperation, training sessions have been classified and programmed to be hard (A), moderate (B), and easy (C). The training routines of the legendary Vladimir Salnikov are reputed to follow a sequence of something like this: A B C A B C A, etc., recognizing the need for extra recovery from an excessively hard training session through a more moderate workload session followed by an easy session. Unfortunately, there has been an unfounded belief in sports that if someone is successful by experiencing heavy workloads, others should be more successful if they experience even greater workloads. While the outliers who are exceptionally stress-tolerant have been successful, many individuals have been driven from competitive swimming because of overwork (and often the stress-related injuries).

When lactic acid rises in a set due to a significant demand on anaerobic energy, it interferes with the manner in which the aerobic system functions (Schneider & Karpovich, 1948). There is some debate as to the mechanisms which cause the disruption but the main symptom is that the size of oxygen uptake increases over that which is needed when not influenced by anaerobiosis. Although much bravado accompanies "lactate tolerance sets", they are accompanied by little regard from the negative and less than desirable effects of that form of training.

The eventual chronic fatigue developed in "hard" swimming programs is normally of a general nature. Unlike the fatigue that develops training effects, traditional swimmers push well past any specific training effects. In that push, the body mobilizes extra (excess) resources to accommodate exercise demands in a less than refined specific way. Strokes shorten, normal ratings slow down, the swimmer's effort levels vary all being below beneficial race-pace, and the energy used is non-specific. Essentially, swimmers are in survival mode which prompts a generalized coping behavior that is not specific in race-pace techniques or energy provision. No gains for improving race performances are developed by pursuing exhaustion.

The symptoms of repetitive excessive fatigue are clear. At the first level of onset, a swimmer's psychology changes (e.g., lowered enthusiasm; notably more negative comments and thought structures; increased silence, moodiness, and isolation; etc.). If the excessive demands are further experienced, the second level is reached. Upon entering this stage technique faults will be noted (e.g., effective distance per stroke decreases; rating in a set task is lowered; action smoothness often gives way to roughness or unevenness; the underwater power-phase develops sudden repositioning; etc.). In the latter stages of the second level, overuse injury symptoms or technique related injuries (e.g., swimmer's shoulder) emerge. Finally at the third level, the swimmer's performance degrades and does not recover despite how many easy sessions are programmed or how many "mornings off" are allowed the swimmer. When the failure of performances to recover or sustain a performance level across sessions occurs, the swimmer will have entered the

Stage of Exhaustion (Carlile, 1955) in Selye's General Adaptation Syndrome[2] (Selye, 1950). At this level of fatigue, a swimmer is vulnerable to injury, diseases, and illnesses because of lowered level of immunity (e.g., a reduced production in anti-bodies) in the immune system (Diagnose-Me.com, no date).

An exhausted swimmer usually needs time-off away from swimming. That will produce the fastest recovery but often with a detraining effect on some aspects of performance. Attempts to keep exhausted swimmers training but with lightened loads rarely succeeds in fostering recovery. When a swimmer is "thrashed" through too much swimming, a vacation from the sport is the surest and most needed remedy.

The onset of swimmer-exhaustion occurs in three stages. Those coaches who follow the "tough training" or the "more-work-is-better" beliefs need to watch for these stages. To ignore them is to put swimmers at risk.

1. Stage 1 is psychological regression. Attitudes, mood, and social interactions worsen because of negativity and phases of isolation from other swimmers.
2. Stage 2 is technique regression. Strokes become less effective, ratings are lower, and rough parts of the stroke cycles appear. An increase in complaints about soreness or injury is likely to occur.
3. Stage 3 is physical exhaustion. The symptoms of the above two stages persist and even worsen. Physical performances deteriorate and do not recover even with short bouts of rest. This is the Stage of Exhaustion for the athlete and the most tried and successful remedy is rest away from swimming practices and its environments.

The difficulties with excessive-swimming exhaustion are: 1) several irrelevant-for-racing training effects might have been experienced; 2) the excessive fatigue is not swimming-specific because it is general; 3) recovery takes a long time (almost universally at least a week); and 4) swimmers innately question the value of the experience/sport. This type of training usually ends in swimmers entering well into The Stage of Exhaustion (overtrained state) and a long taper or rest for recovery is needed. The single label used to describe excessive pool work is "misadaptation".

The Ugly – Traditional Pool and Land Training

The worst kind of swimming training is where both hard work in the pool and on land are scheduled and expected of swimmers. The effect of this type of training also fits in with the "survival of the fittest" model. Swimmers are worked mercilessly with little regard to how they perform at practice (showing a complete disregard for developing practice effects). Underlying this form of coaching are three major unfounded beliefs.

1. The harder swimmers work, no matter what the work entails, the better they will perform.
2. While swimmers are exhausted and swimming poorly at practices, something "good" is happening to them which will be revealed after a taper.
3. Land work has valuable carryover to water work. [While this might be true for beginner swimmers (Hager et al., 2011), the evidence is available to show this to be a fantasy and that land work is not related to top swimmers' performances (e.g., Sokolovas, 2000).]

[2] Selye's GAS is as relevant today as it was more than 60 years ago. It is a useful model upon which to base decisions concerning the adaptability of athletes to exercise stress.

There are two parts to this training format. The first is land training which is often emphasized more than pool training. This is strange because there is a wealth of evidence that shows physical capacities (e.g., strength and power) gained on land activities (e.g., fixed weights) including swimming simulators (e.g., Swim Bench) have no relationship to swimming performances (Neufer et al. 1987). Capacities such as strength are not related to female swimmers' successes and of minor importance to males (Sokolovas, 2000). If it were possible to transfer training benefits to competitive swimmers, at least four criteria would need to be met: 1) movement pattern, 2) contraction type, 3) movement speed, and 4) contraction force – all would need to replicate what is done in the sporting movements (Rushall & Pyke, 1991). It is obvious that the only way strength training could meet these criteria is to swim as fast and as hard as possible.

An emphasis on land-training for strength promoted by the unfounded belief that it will benefit serious swimmers' performances is a waste of time and therefore, changes it provokes are evidence of mal-adaptation. In essence, an emphasis on land-training as part of coaching is mal-practice. However, there are times when land-training might influence swimmers. In very young and weak individuals it could serve as a stimulus to promote balanced growth, rather than swimming-specific growth, and therefore has the potential to affect the health and growth on young people (Rushall, Marsden, & Young, 1993). If injured swimmers are in rehabilitation, the application of overload stimuli can stimulate restoration in the affected skeletal structures. Finally, in learn-to-swim participants some mild strengthening exercise could assist in developing passable competencies in the water. This latter example is an instance of a number of paradoxes that exist in swimming, and to a large extent, to sports in general. The paradox is that activities that benefit neophyte swimmers are often irrelevant or counterproductive for experienced swimmers.

It is also irrelevant to train serious swimmers with land- and water-exercises (e.g., equipment and drills) because there is no way such irrelevant and disparate activities benefit serious swimmers (Rushall, 2011) although paradoxically they could benefit learn-to-swim participants. A common training item, assisted- and resisted-swimming using elastic bands, altered the mechanics of serious swimmers in a detrimental way (Maglischo et al., 1985). Because of the Principle of Specificity of Training (Rushall & Pyke, 1991), there is no way an unrelated activity would stimulate the same area of the brain in a beneficial manner to enhance the neuromuscular patterning of the very skilled activities of those in sports such as competitive swimming.

The inclusion of irrelevant training items for swimming is quite prolific and proselytized by specialist strength trainers, conditioning coaches, etc., whose employment depends upon having customers. This writer has experienced the disastrous effects of auxiliary land-based weight training on swimming practices. On several occasions after finishing one-hour of heavy weight exercises swimmers stated they were *"so sore in the thigh, buttocks, and hip areas that they could not even sit on the toilet"* (personal communications [names withheld], October through December, 2011). With that perception they attempted to train in the pool which resulted in no meaningful swimming being experienced. The scheduling of resistance training before swimming practice is inadvisable (Doncaster & Twist, 2012) even if it is the *"only time for doing the strength work"*.

Coaches should be aware that interfering with or giving up pool time for land-based or drill activities in the belief that they are beneficial is unfounded in and contradicted by science. It is not the intention of this paper to present a full discourse on the latest scientific findings regarding auxiliary training activities (i.e., the irrelevant activities for competitive swimming). However, Table 1 contains an incomplete checklist of the latest research into primarily weight training that could be used by coaches to evaluate the services provided by outsiders or included in their own training programs. If these features did not exist in a program that is legally challenged for being injury-producing or abusive, the defendant would be defenseless.

TABLE 1. A SELECTION OF RESEARCH PRODUCED PRINCIPLES THAT SHOULD BE PRESENT IN ANY STRENGTH-TRAINING PROGRAM.

Number	Principle Revealed in the Research Report	Reference
1	Auxiliary training should not precede water training.	Doncaster & Twist (2012); Hakkinen, Kraemer, & Gorostiaga. (2009).
2	Maximal and explosive strength training have different specific adaptation effects. So, for which are the swimmers training?	Tilllin, Pain, & Folland (2012)
3	Effective resistance training does not require *"going to failure"*. Are your swimmers over-working?	Sundstrup et al. (2011)
4	One set of resistance exercises produces maximal fatigue. Are you still doing three sets?	Jakobsen et al. (2011)
5	Low rather than heavy weights influence endurance development. What is being developed in your program?	Mathis, Kim, & Yang. (2011)
6	Natural movements as opposed to machine restricted movements produce the greatest gains in auxiliary exercise training.	Padua, DiStefano, & Clark. (2010); Turner et al. (2010)
7	Strength and power are only improved in the activities used to train them. So, do not expect any benefits to transfer to free-swimming.	Duchateau (2009).
8	Slow movement isokinetic training does not transfer to faster movements. It can be argued that this pertains to any form of contraction.	House et al. (2010)
9	Fast strength training movements are better for fast and powerful movements. If there was transfer, resistance exercises should be fast for competitive swimmers.	LeFavi et al. (2010)
10	Novice resistance trainers improve through skill acquisition, not structural changes. Improvements come from learning to do the exercise, not from becoming "stronger".	Pearce, Grikepelis, & Kidgell. (2009)
11	Excessive stretching reduces muscle elasticity.	Hoge et al. (2009)

The above diversionary discussion was provided to illustrate just how irrelevant and potentially dangerous are many land-based "strength" or resistance-training programs. Being both dangerous and irrelevant for improving the performances of serious swimmers causes one to wonder why they are included in swimming training. The usual social reason for that question is that dogma dictates the behaviors of those involved. The land-based activities and non-swimming water-based activities that have no transfer of training effect to swimming racing is one of the features of an "ugly swimming program".

The second feature of this training is pool work. The quality of in-pool work is often compromised because of various levels of externally-caused fatigue that exist when a pool-practice begins. As well, valuable pool time is wasted by using inappropriate devices and drills that have no benefit for serious swimmers. The big picture of this type of swimming program is that very little satisfactory swimming is performed and when it is, a traditional program will exacerbate fatigue before promoting any specific-race training.

Many swimmers experience this type of program and still improve. Mostly, improvements are promoted by growth which has a large effect on performance. The benefits of growth are thwarted by excessive swimming programs. When the developments are meager, the eclipse by mal-adaptive work is not quite complete.

Among swimming dogma is the belief that swimmers need to experience excessively demanding training in order to become a champion. While some of those who survive such programs go on to achieve swimming success, there are many potential champions who fall by the wayside through intolerance of the demands or the overwhelming de-motivation that accompanies long-term stressful experiences. Since successful swimmers are usually characterized by superior techniques and a maximized individual level of fitness, it is disappointing to know that *"hard work* [of any form] *is the road to success"* is embraced by top-level coaches. Given the opportunity to recruit swimmers with inducements of one kind or another, within-team personal improvements are often rare. Too many swimmers go on to college or change programs after their growth is complete and do not exhibit performance improvements for the rest of their careers. Such stagnation means that the programs in which they are training do not provide any stimuli that are likely to promote improvements in swimmers' preferred events.

When land- and pool-training programs are excessive and often riddled with irrelevant-for-competitive-swimming experiences, they represent mal-adaptive programs. Coaches who foster mal-adaptive programs are guilty of mal-practice.

Coping with Fatigue

It is reasonable to assert that the fatigue from traditional swimming training differs from that incurred in USRPT. A taper period (rest and restoration) is the most common attempt to cope with continued debilitating fatigue in traditional training. On the other hand, the neural fatigue of USRPT can be effectively handled with a day or two of training at a reduced work volume but maintained race-pace quality. There is considerable research literature on taper formats.

Of particular but neglected importance is the fatigue that occurs in races. Coping with that fatigue differs between a physiological and a psychological perspective.

The physiological explanation is clearly depicted by Asmussen (1979).

> *In peripheral muscle fatigue there are at least two different sites where repeated contractions may cause impairment: the "transmission mechanism" (neuromuscular*

junction, muscle membrane, and endoplasmic reticulum), and the "contractile mechanism" (muscle filaments).

As the mechanical response of the individual active muscle fibers decline with fatigue, a certain compensation can be achieved by increasing the innervation frequency and/or the number of active motor units. The reasons for the appearance of peripheral muscle fatigue are local changes in the internal conditions of the muscle. These may be biochemical, depletion of substrates such as glycogen, high energy phosphate compounds in the muscle fibers, and acetylcholine in the terminal motor nerve branches, or they may be due to the accumulation of metabolites, such as lactate or electrolytes liberated from the muscles during activity.

In short-term maximal or near-maximal isometric contractions, it is highly improbable that a general depletion of the energy stores should be the direct cause of exhaustion. The only substances that specifically undergo a significant decrease are the high energy phosphates, especially creatine phosphate (CP). The decrease of high energy phosphates is not due to a depletion of energy stores. It is due to a too low rate of energy transfer from the stores to the ATP and CP. This slowing, presumably of enzymatic processes, might be caused by the concomitant increase in muscle lactic acid, causing a pH decrease. Accordingly, lactic acid might be termed a "fatigue substance". However, there are several other possibilities particularly if transmission fatigue is present. Thus, both the contractile and transmission mechanism may be impaired by continuous muscle activity.

[Paraphrase by editor - http://coachsci.sdsu.edu/csa/vol65/asmussen.htm]

The usual interpretation of this form of description is that performance decline can be offset by trying harder, that is, increase the cognitive intensity level of the whole action. Such an explanation is inadequate (Noakes, 2012). Increasing the intensity/effort level of a fatiguing task only accelerates the accrual of fatigue and performance decline (Rushall, 1979, 1995, 2008). The often noted instruction to *"pace yourself so that you will have energy to put into a strong finishing effort"* directs a swimmer's attention inappropriately.

On the other hand, the USRPT emphasis on technique has received recent validation. For years, this writer has been advocating that instead of trying harder in fatigue a swimmer should concentrate on the elements of technique with intensified specific thought processes. The evidence for that alternative resided in several research papers when taken as a whole produced that coaching principle. Watson, Wood, and Kipp (2013) presented a paper that supported the general principle. Figure 1 contains an abstract of that presentation. It provides evidence that in fatigue, an athlete should concentrate on technique (movement efficiency) and not on a greater effort level.

For swimmers to be able to concentrate on technique elements in races, they first need to have an in-depth understanding of swimming techniques so that actions that effect movement efficiency are prolonged by an increase in directed-thought intensity. Rushall's books and manuals on the formulation of pre-race and race strategies include descriptions and examples of the elements on the structure of self-talk about technique and the little known psychological procedure of thought intensification (Johnson, 1991; Martin, 1989).

USRPT primarily focuses on technique instruction (Rushall, 2014). Pedagogical aids and descriptions of technique elements for the four competitive swimming strokes are contained in Rushall (2013d, 2013e). Swimmers need to be instructed in race-segmenting, task-specific thought content, positive thinking, mood words, and thought intensification mental skills. That instruction should be a consistent and large part of swimming practices in the USRPT format.

The resources are available and a holistic research study focusing on effort level and technique emphasis to validate those resources are now available. This is one more indication that swimming coaches, and indeed coaches in all sports, should change to a cognitive controlled emphasis on the maintenance of movement efficiency as fatigue increases in training tasks and competitive performances.

Watson, K. D, Wood, C. M., & Kipp, K. (2013). Fatigue deleteriously alters muscle activation patterns during landing and cutting tasks. Medicine & Science in Sports & Exercise, 45(5), Supplement abstract number 462.

This study investigated the effects of fatigue on muscle activation during landing and cutting tasks in active college-aged Ss (M = 7; F = 5). Ss performed three athletic maneuvers that included a maximal vertical jump, single-leg landings, and 45º side-cuts. Five trials of each task were collected before and after (a continuous 4-minute fatigue circuit that consisted of i) a forward sprint, ii) a backward sprint, and iii) a side-step/vertical jump drill (all distances were 12.5m). During the single-leg landings and 45º side-cut tasks, Ss jumped forward onto a force plate, landed on a single leg, and either stabilized or cut laterally at 45º, respectively. Wireless EMG electrodes were attached to five thigh muscles (i.e., rectus femoris, vastus medialis, vastus lateralis, medial hamstrings, and lateral hamstrings). EMG data were rectified, band-pass filtered, smoothed, and normalized to maximal voluntary contraction obtained from manual muscle testing. Peak-landing phase EMG averages were calculated for each muscle and for each task. Pre- and post-fatigue averages were compared.

Vertical jump height decreased after exercise however, the decrease was only significant for 6 of the 12 Ss. With fatigue, muscle activations (%MVC) were greater for the vastus lateralis and rectus femoris during single-leg landings. There was a non-significant trend towards greater muscle activation for the vastus lateralis and rectus femoris during 45º side-cut tasks after fatigue.

***Implication**. When fatigued, landing and cutting tasks are completed with greater rectus femoris and vastus lateralis activation. Since greater vastus lateralis activation is associated with greater knee valgus torque during landing (i.e., a risk factor of non-contact knee injury), the observed changes in muscle activation may increase the risk of injury.*

"Fatigue produces exaggerated muscle activation with no concomitant increase in performance but rather, a decrease in performance. Consequently, trying harder in fatigue will only heighten the onset of more fatigue and probably degrade performance more. To be more efficient, an athlete should force the body to be more efficient by consciously focusing on performing efficient movements. In most instances of fatigue, athletes should try to perform better (a technique emphasis) rather than harder."

Figure 1. An abstract of Watson, Wood, and Kipp's (2013) presentation that demonstrated the validity of concentrating on technique features when an athlete begins to fatigue.

Closure

Three classifications of swimming programs were briefly described above. Each is differentiated by the amount and type of exhaustion developed by the activities in their training formats. What differentiates the programs is the dogmatic attribute of demanding exercise yielding high levels of exhaustive fatigue being stressed in two while the USRPT program limits the possibility of exhaustion but maximizes the occurrence of race-specific training effects. It is contended that there is good fatigue (training effects) and bad or ugly fatigue that epitomize general fatigue that suppresses performance, prevents the learning or refinement of appropriate skills, and is associated with injury and/or illness.

A swimming coach should choose the training classification that benefits swimmers most.

Coping with fatigue is best achieved by intensifying thought processes aimed at maintaining good technique. Increasing effort as fatigue starts to negatively effect performance only serves to increase the speed of onset of extreme fatigue.

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