SWIMMING SCIENCE BULLETIN

Number 60d

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Professor Emeritus Brent S. Rushall, San Diego State University

USRPT AND TRAINING THEORY IV: THE RECOVERY PRINCIPLE

Brent S. Rushall, PhD

December 25, 2016

The Recovery Principle

A swimmer's improvement is dependent upon the provision of adequate recovery so that training effects can be maximized. The *Recovery Principle* implies that for maximum performance benefits and before a training stimulus is reintroduced, complete recovery from the previous stimulation should occur. To train without adequate recovery from previous fatiguing work does not produce any benefit to swimmers for they merely learn to cope with general fatigue rather than improving in specific aspects of swimming performance.

Recovery from three sources of fatigue is necessary in USRPT.

- The fatigue of a specific-training stimulus which is primarily neural in nature;
- the general fatigue that results from the accumulated stress of a total training session which is both physiological and psychological; and
- long-term fatigue that results from entering the Exhaustion Phase in the overall General Adaptation Syndrome.

The latter form of fatigue is physiological, psychological, and biomechanical (the disruption of neuromuscular patterns) in nature. The importance of recovery and avoidance of extreme fatigue from each of these sources should be a central concern of coaches and swimmers. The positive relationship between fatigue and recovery time is the underlying moderator of recovery planning. The greater the state of fatigue, the greater is the time that needs to be allocated for recovery. However, excessive recovery time could lead to the loss of temporary specific-training effects. The timing of the regeneration/overcompensation reaction is critical for producing performance improvements.

The rate at which a swimmer recovers from any source of fatigue determines the rate at which training can progress. Individual differences moderate recovery rates and so programming of training stimuli and sessions will depend upon a swimmer's capacities. A failure to adapt training programs to every swimmer's needs for recovery represents poor coaching. Training programs need to be planned to accommodate the recovery requirements of each swimmer.

If recovery between successive training stimuli and sessions is inadequate, general fatigue will accumulate and adaptive specific-training processes will not be evident. That results in delayed adaptation, performance decline, and an increase in the likelihood of injury and/or illness. The benefits of training and competitions are not achieved unless a coach emphasizes the recovery process with at least an emphasis equal to that afforded overload. The most important factor that affects an athlete's health status is the alternation of overload stimuli with adequate recovery between each presentation.

Recovery between Repetitions within a Training Segment/Set

When a USRPT set is attempted, the goal of a swimmer should be to equal or exceed their previous best: i) number of repetitions completed before the first failure, and ii) the total number of successful repetitions completed before the set-failure criterion is reached. The intent of each repetition should include performing consistently at the designated race-pace so that the swimmer learns how to swim long tasks maintaining a particular pace but gradually using minor technique alterations which require different energy resources and mental control that will enable the swimmer to sustain that pace.

When the ~15 or ~20 seconds of rest occurs between the repetitions within a USRPT set, immediately upon termination of a repetition the swimmer should move to the lane line so that the wall center is unobstructed as well as keeping away from a position that might block a following swimmer's vision of the pace-clock. Physiologically, swimmers should be breathing heavily in order to restore the stored-oxygen resources employed in the just-completed repetition, as well as restore any anaerobic resources that might have been used. Right from the first rest period, swimmers should exaggerate the depth and frequency of their breathing and not wait until the urge to breathe more occurs (which could be too late).

Understanding that there is considerable variation between swimmers within a squad, at approximately half-way through a set swimmers will have to try harder to maintain the desired pace. A strategy for increasing the effort level and concentration intensity on technique maintenance usually should be the central focus of the thought content that occurs in the brief rest. Swimmers should be taught what physiological and psychological resources they have at their disposal for *"pushing through"* the difficult and challenging part of a USRPT set. For example[1], if a set designed for a 200 m freestyle race is attempted using 50 m as the repetition distance, the first four repetitions could be rehearsals of how the first 50 m of the next race to be attempted will be swum. Repetitions 5 through 8 could rehearse the second 50 m of the race; repetitions 9 through 12 could be the third 50 m, and from 13 on each repetition should practice how the race will be completed. For swimmers who cannot complete a minimum of 16 x 50s at 200-m race-pace, the number of repetitions used for race-stage rehearsals should be reduced proportionately. Similarly, for swimmers who complete a substantially greater number of successful repetitions the number of repetitions for each race-stage should be increased proportionately. Swimmers' thinking during within training-segment rests is the time that should be used for constructive and dedicated thinking to learn how they need to focus intently so that they will not be distracted by factors over which they have no control during races.

Some studies have structured the research tasks in a manner that suggests within-set recovery activities. Toubekis *et al.* (2005) and also Toubekis *et al.* (2006) had swimmers perform 6 x 50 m freestyle sprints with 45 or 120-second rest periods. Passive and active recoveries were

[1] This is an example of practicing some psychological content in a USRPT set.

compared. Passive recoveries were best at maintaining performance levels within the set although active recovery removed more lactate. However, since lactate build-up is not a major factor in USRPT, passively remaining in the water and spending the time to mentally prepare for the next repetition is acceptable. Buchheit *et al.* (2009) and Zadeh *et al.* (2012) found that in-water recovery was better than out-of-water recovery between repetitions within a 6 x 50 m maximum sprint set. Since the rest periods were much greater than occur in USRPT sets. They are possibly associated more with Sprint-USRPT sets. There is little relevance of these studies for between-repetitions USRPT activities except for staying in the water and waiting for the next repetition to begin as being acceptable.

When short between-repetitions rests occur, the activities of the swimmers should be associated more with organization, such as ensuring there is no hindrance to swimmers completing their repetitions and commencing the next repetition on time. The rest of the time should focus on mental preparation and moving quickly to a position where a fast start on the repetition interval can be initiated. What a swimmer does and thinks during within-set rests is an important part of the mental development of swimmers in USRPT programs.

Recovery from a Training Stimulus within a Training Session

After a USRPT training stimulus has exceeded an athlete's threshold capacity and neural fatigue is evident, the activity should cease. To work any longer would not result in performance enhancement. Recovery permits the re-establishment of all stressed systems to full functioning. Overcompensation involves the morphological reorganization of these functional systems to perform better during repeated exposures to the original stimulus. The functional systems are both physiological and psychological in nature. At one extreme, for pure physiological fatigue, the regeneration of physiological functions is emphasized. At the other extreme, when psychological fatigue occurs, such as when training is boring, lacks swimmer feedback, or contains activities which the athlete believes yield no swimming benefits, psychological capacities and their underlying physiological components are regenerated. Allowing the central nervous system to recover from stressful stimulation is often neglected in conditioning-oriented coaching systems. Effective training allows time for both processes to occur (*Sports*, February & August, 1986).

The adaptation to event-specific training stimuli is the result of the correct alternation between work/stimulation and regeneration/overcompensation. Regeneration is initially fast but then it slows. The absolute time for recovery depends upon the individual, the level of fatigue incurred, the energy systems involved, and a number of moderating factors. Some of those moderating factors are discussed below.

1. Both fatigue and recovery will occur more quickly in simple than in complex activities and performance will improve and reach its maximum level in a seemingly shorter period of time.
2. Fatigue will take longer to occur if the technical proficiency of performance is high[2]. This is because less energy per repetition of the exercise is used in more competent performers. Changes in technical/propelling efficiency partly explain why performances

[2] In swimming this is known as *propelling efficiency* or *propelling proficiency,* improvements that result mainly from technique instruction.

continue to improve after physiological capacities have reached their maximum maturation level. Examples of this are clearly seen not only in swimming but in running and rowing. In activities where energy use is a primary factor, the efficiencies of techniques will be a major determinant of performance, and training emphases should accordingly reflect this. Training must be specific to produce the greatest rate of physiological and skill adaptation (Treffene, 2010). USRPT is the format for doing that.

3. The effects of specific volumes and intensities of training vary from improving sprint events that use explosive power and stored oxygen and anaerobic mechanisms to making both the central and peripheral adaptations that are important in aerobically dominated events. The degree to which these effects occur depends upon the nature of the training stimulus. The particular mix of response components will dictate that different recovery times will be required for different events and their energy requirements.
4. The nature of the work done affects recovery speeds. The time it takes to recover from exercise with a substantial component of eccentric work, such as running, is slower than that following the predominantly concentric work experienced in swimming (O'Reilly *et al.*, 1987). Running places a higher degree of strain on the musculoskeletal system than do other activities. This explains why it is a questionable procedure to use the parameters and training principles of running programs for swimming. With swimming not having to fight gravity and being performed in a prone or supine posture causes the body structures and physiology to react differently to most terrestrial sports. Swimming and its variants are unique among many non-combative sports where performances are simply unhindered by other competitors. The work-to-rest ratios of swimming are different to those of terrestrial endurance activities. Swimming coaches and performers need to be aware of the subtle nuances that swimming training requires when compared to terrestrial activities.
5. Complex activities fatigue at slower rates than do simple activities. The complexity allows a family of neuromuscular coordinations to develop to achieve similar functional outcomes. It is not unusual for swimmers to cycle through these alternative functional patterns while performing in a specific race. Competing in medley events takes that feature to a much more complex level. Since each pattern uses some different muscle fibers, while one pattern is being used some fibers associated with another can recover. Minor alterations in techniques of sports which are cyclic in nature (e.g., swimming, rowing, cycling) occur as the activity progresses without any diminution in performance level. These technique alterations are also forced upon the swimmer due to changes in race demands. Thus, fatigued sites incurred while swimming will partly recover in the non-swimming sections of a race (i.e., the dive, underwater work, the turn approach, turn execution, and underwater work off the wall). Although those phenomena involve muscle fibers, they are also differentiated by the swimming event stroke, distance, and rules. As well, the competitive swimming events involve different strokes which have vastly different muscle usage and coordination. That is why some swimmers are brilliant at one stroke/event and average in others.

There is scant research about the completion of a set within training-session recovery. At best, one could analogize the popular research strategy of investigating recovery after time-trials, race simulations, and short maximum efforts. That might be satisfactory for traditional training but it is inappropriate for USRPT programs. Some of the great advantages of the USRPT short-work short-rest format for a race-specific set is that i) the high rate of work can be sustained in a much greater volume than is possible with traditional work; ii) lactate (lactic acid) build-up is minimized, and iii) glycogen depletion is very slight even when the stage of neural fatigue is evidenced. Low lactate and high glycogen levels sustain an internal atmosphere where learning is possible, which frequently is not possible in a traditional race-simulation exercise. The greater number of actual event-specific strokes is so much higher in USRPT work, that the ability of the body to energize the movement patterns that are cycled throughout a race is greatly enhanced. However, USRPT still requires a definite set of swimmer behaviors to be evidenced so that training proficiency can be maximized. If swimmers are not honing techniques and skills in a USRPT set, then lesser-intensity recovery time and time dedicated to those technical features can be used to further their practice as well as apply time to working on swimming fast (Sprint-USRPT) in the most efficient manner.

After the completion of one USRPT set, recovery is in order. Since the competitive swimming strokes require large differences in the musculature and energy resources used, one programming procedure would be to have markedly different strokes alternating in the program. If the competitive strokes are classified as *alternating* (i.e., freestyle and backstroke) and *symmetrical* (i.e., breaststroke and butterfly stroke) forms, then the effect of fatigue from one form of swimming will be lessened if the next stroke to be trained is from a different form. A sequence of breaststroke-backstroke-butterfly-freestyle would be better for swimmer performances than a freestyle-backstroke-breaststroke-butterfly sequence. The latter sequence does not maximize the difference between successive repetition sets.

USRPT sets do not deplete glycogen stores or elevate lactate levels significantly. Consequently, post-set recoveries should be relatively short (~15 minutes or less) and certainly shorter than after-race recoveries. Most research has used time-periods that are more appropriate for grueling race-recoveries than for USRPT training sessions. No matter what the required duration, active recoveries are better than passive recoveries (Denadai, Guglielmo, & Denadai, 2000; Felix *et al.*, 1997; Greenwood *et al.*, 2008; Mota *et al.*, 2013; Reaburn & McKinnon, 1990; Weltman *et al.*, 2005). The post-race-simulation research has primarily focused on lactate removal. The observations reported have shown that swimming of a limited duration (e.g., ~15 minutes) removes lactate to a much greater degree than passive recoveries but the removal is only partial (Denadai, Guglielmo, & Denadai, 2000; Felix *et al.*, 1997; McMaster, Stoddard, & Duncan, 1989; Mota *et al.*, 2013). A number of the above referenced articles appear to have assumed that swimming was the best activity for recovery and have reported that velocities in the range of 60-65% maximum velocity (Mota *et al.*, 2013; McMaster, Stoddard, & Duncan, 1989) or at lactate threshold (Greenwood *et al.*, 2008; Weltman *et al.*, 2005) are the best paces to be used for after-race recoveries. Plusch *et al.*, (2010) opined that recovery activities need not only be swimming. The reasoning behind that assertion is sound. When fatigued from a stylized repetitive activity such as swimming, not all muscles in the athlete are driven to exhaustion. Improved lactate clearance appears allied with active recovery regardless of the mode of exercise. Consequently, in situations where in-water recovery activities are not possible, an out-of-water activity program can assist in recovery acceleration.

The implication of the Plusch *et al.* study is particularly relevant to USRPT training and between-sets recoveries. Swimmers complete USRPT sets at different times. Unless there is a dedicated recovery-swimming lane in the pool, swimmers that have reached the failure criterion for terminating the set should exit the water and immediately start an activity sequence that uses as many muscles as possible (e.g., walking while doing arm activities as well as bending and twisting the torso). As soon as the last swimmer in a lane fails, all swimmers in that lane should reenter the water and commence swimming at about 60-65% repetition velocity. Having the swimmers get out of the lane creates better swimming conditions for those still working in the set as well as giving the *"early failures"* something to do that will be beneficial. Between-sets recovery time is also a time when bathroom-breaks and equipment changes can be made without jeopardizing any beneficial training opportunity.

While the partially-related research mentioned above indicated that the length of time for a total recovery is more than 15 minutes, the low lactate levels generated by USRPT sets would not require large amounts of time for recovery. Not all lactate needs to be removed from the system. Low levels will actually be beneficial because some lactic acid will be used as a source of energy by active muscles particularly by the heart. Thus, it is recommended that between-sets recoveries in USRPT be no more than 15 minutes and no less than 10 minutes after the last swimmer has terminated swimming the set.

The activities that can be used for between-sets recoveries can include out-of-water activities that should involve as many muscle groups as possible and be constantly moved for the duration. In-water swimming should also vary the strokes so that non-fatigued muscles will be used to reconstitute the blood and performed at a pace that is faster than *leisurely paddling*.

Recovery procedures should be an integral part of a training session. Altering activities and scheduling them in particular sequences can facilitate recovery. It is not always necessary to wait for complete recovery before commencing a new training stimulus particularly if considerably different muscle groups and techniques are used. By alternating exercises and stimuli, substantial training demands can be made without compromising the recovery process for specific stimuli. Rest intervals cannot be considered *"true recovery periods"* while parts of the body are still working. Rest interval demands will govern the adequacy of recovery for specific-event training stimuli. Alternating activities does, however, allow some recovery to occur. The rate of recovery will depend on the degree to which the alternated activity generates lactic acid and the amount of use of already fatigued muscle fibers. In USRPT, the lactic acid factor is of minor importance.

Recovery from Training Sessions

Each training session has an accumulation of general fatigue states and products that occur from the training stimuli experienced. Recovery after an exercise session primarily involves replenishing depleted energy stores, removing accumulated metabolites, and repairing damaged tissue. The stress of a training session is both psychological and physiological.

Serious and demanding training sessions cause a reduction in an athlete's ability to perform during and immediately after each training session. The skilful manipulation of the training loads encountered during a session is usually one way of ensuring that excessive fatigue does not accumulate across sessions. Two ploys are used to guard against the accumulation of fatigue. The first involves a load reduction for each stimulus in the last step of a microcycle. This will serve as a safeguard against overfatigue and will reduce the accumulated stress of the sessions within the microcycle. The second strategy involves the consideration of the strain of each training session. Although USRPT attempts to reduce strain when compared to traditional *hard* training, sessions still vary in their strain value. A plan is that levels of strain occur, such as hard, medium, and light loads. Following a hard session with a light session will possibly allow further recovery to take place or at least will not add to the need for recovery, whereas one hard session followed by another may diminish the intended value of the second training session. Because of accumulated general fatigue from the two hard sessions it may take even longer to recover from two adjacent sessions than from each session conducted individually, interspersed with a lighter load session. The sequencing of different training session stresses will allow recovery to occur so that productive work can be conducted across the total microcycle. However, plans are all well and good but in USRPT if swimmers appear to be fatigued and not producing many best-ever set performances, a light USRPT session should be conducted to allow recovery rather than fatigue to occur from the stimulus.

In traditional training, it is possible to have training sessions that are too long and develop fatigue states that are more destructive than helpful, particularly in a neuromuscular sense. There comes a time when the accumulated fatigue within a training session is of sufficient potential harm that the session should be terminated. Coaches should avoid having swimmers reach that critical state.

After either training session of the day, the speed of recovery is not an all-important factor but it is helpful if it can be achieved quickly. With USRPT, the low-level fatigue at the end of practice is not a major factor. USRPT coaches often remark on the differences between USRPT-trained and traditionally-trained swimmers after practice. USRPT swimmers are more spritely, *"chirpier",* and energetic upon completion of training. However, using recovery activities after a training session can accelerate recovery from fatigue no matter how severe it might be. The activities after the training session should serve to disperse fluid and metabolites from the muscles and reduce residual soreness. In USRPT, session-recovery activities take place on land and involve changing and traveling home. General activities that involve as many muscles as possible can serve recovery purposes. The addition of extra movements as well as what is involved with showering, changing, and leaving the pool will assist in the transition from pool activities to everyday activities. It is wise, from a motivational point of view, as well as for physiological reasons, to have athletes leave training or competitions in at least a partly recovered state.

Recovery is more difficult if swimmers train two times per day. Light load or restoration sets shuold be included to permit recovery from the main specialized training stimuli. It is important to avoid closely spaced event-specific sets of USRPT work. It is recommended that specialized training stimuli be experienced at least 36 hours apart but in some situations 24 hours could be acceptable. Light-intensity sessions (unloading sessions) can be used as strategy teaching sessions while the functional capacities of the neuromuscular system are restored.

Diet is important in the recovery process. Protein, the important nutrient in tissue building, repair, and growth is required after prolonged intensive sets of repetitions. As well, protein also prevents muscle breakdown (Troup, 1991). Sufficient protein should be consumed for repair and restoration of tissues and for growth in age-group swimmers. Tissue damage is low in swimming when compared to other sports. The low tissue costs are due to the absence of collisions and hard surfaces encountered in the swimming strokes. It is recommended that protein supplements be consumed early in a recovery period in age-groupers so that growth will not be compromised by the need to recover from exercise stress. This increase is usually from the recommended daily protein intake of 1 gm/kg to between 1.5 and 2.0 gm/kg. This can be easily met from an increased food intake, including milk, and does not require supplements (e.g., commercial protein powders, pills) that are commonly used by strength athletes and body-builders.

Carbohydrate is needed to fuel the excessive demands of swimming training. Troup (1991) estimated that swim-training sessions often require fuel volumes equivalent to those used in running a marathon. Replenishing carbohydrate reserves used at a swimming practice should be a primary aim of foods and fluids consumed after both morning and afternoon practices. Replacement carbohydrates should be complex (e.g., unprocessed grains, rice, potatoes, etc.) and not empty (e.g., refined sugary foods and drinks).

Foods with high fat content (e.g., fast foods) should be avoided in the early stage of post-session recovery because they slow the digestive process. However, some fats usually need to be consumed because they are a much greater concentrated source of calories than are complex carbohydrates.

The most acceptable protein and carbohydrate supplement is low-fat chocolate milk. The reason that low-fat milk is advised is that the fat content in fully constituted milk slows the absorption of the protein and carbohydrate content. The sooner those two substances are consumed, the faster will be recovery. Research has consistently reported that chocolate milk is a good recovery beverage (Karfonta *et al.*, 2010; Karp *et al.*, 2004), is as beneficial as commercial recovery products (Lunn *et al.*, 2010; Pritchett *et al.*, 2009), it is a preferred recovery beverage (Lindeman *et al.*, 2008) and at least acceptable and tolerated (Gilson *et al.*, 2009).

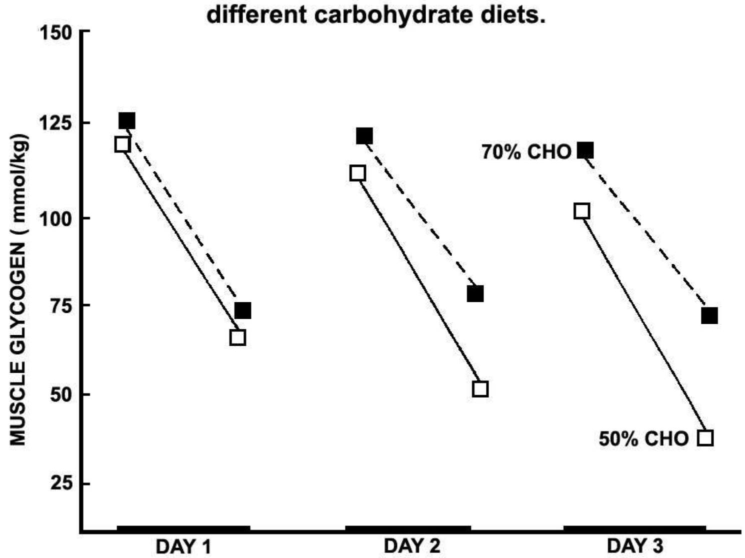
The rate of muscle glycogen synthesis is increased by a diet rich in complex carbohydrates, to which chocolate milk can contribute significantly. Sherman (1987) showed that an elevation from 50 to 70 percent carbohydrate in the diet during successive days of hard training significantly improved muscle glycogen repletion rate. If the need be[3], this strategy can normalize muscle glycogen within 24 hours, down from a possible 36-48 hour time requirement (see Figure 4.1: the 70 percent diet facilitated almost complete replenishment within 24 hours, whereas the 50 percent diet showed incomplete recovery producing a gradually worsening state).

What has to be realized is that in the past there has not been enough attention paid to the diet and energy replenishment of swimmers. Coaches should realize that energy and tissue replenishment needs to occur in normal life-activities as well as swimming. Swimmers' diets have to take into account swimming and normal-life demands. It now seems that these are more important for contributing to performance deterioration than the more commonly ascribed causes. It is in a swimmer's best interest to ensure that adequate fuel is available for training. If there is depletion, then the best training program and coaching in the world will not induce improvement. The body is just not capable of responding appropriately in an adaptive manner when it is fueled inadequately.

[3] The need often arises in age-group swimmers when training stress, outside-of-swimming stresses, and growth needs occur simultaneously. Carbohydrate and protein resources are used extensively in demanding life-styles leaving growth to occur primarily in the evening and during sleep hours. Thus, the evening meal and supplements need to ensure that swimmers recover and sleep with substantial carbohydrate and protein resources readily available.

During a week of training, it is possible that glycogen and protein insufficiencies arise because of accrued inadequate replenishment. The first few days may be tolerated because sufficient stored glycogen is available. With each successive day reserves are depleted and not restored because of dietary inadequacy. Consequently, as the week progresses performances worsen and improvements become inhibited. That can happen as much in USRPT programs as it does in traditional training programs. Proper feeding may be a means of increasing the volume of good swimming that is performed each week.

Figure 4.1. Muscle glycogen depletion and resynthesis during successive days of hard training under two different carbohydrate diets.



It is now appropriate to consider fuel and protein insufficiency as the first possible cause of performance deterioration during prolonged periods of training.

For coaches who believe that land-based resistance training somehow benefits swimming performances, recovery is complicated more than it should be. The time required for recovery of different physiological capacities (e.g., strength, flexibility) varies greatly, as does the time for the replenishment of biochemical substrates. Creatine-phosphate reserves are replaced very rapidly. However, the replacement of glycogen stores and the mending of damaged muscle elements take a markedly longer time. Connective tissues (tendons and fascia) and supportive tissues (ligaments) take the longest time of all functions for recovery primarily due to their decreased vascularization. The circulatory system requires a moderate amount of time for recovery when compared with other systems. Attempts to recover quickly must be directed primarily at those systems that need more time to recover. This requires a coach to modify the intensity and volume of training by scheduling the occurrence of stimuli that are associated with different physical capacities at different times during training microcycles. The most significant factor in sequencing swimming and land-based training experiences is that land-based activities should never precede pool work. A coach should remember that strenuous land-based activities take 36-48 hours for recovery to occur. If pool-training occurs during that time the quality of the swimming-training experience will be affected detrimentally.

Today's training loads and life styles are so demanding that *"natural"* recovery alone can no longer provide adequate recovery. It is part of modern training lore that certain activities are needed to accelerate recovery to facilitate a more frequent occurrence of training stimuli and stresses. An increase in the volume of quality training (e.g., USRPT) has been effective in producing the elevated performance levels that are witnessed in modern sport. Methods for accelerating recovery are necessary to train today's athletes.

Recovery from training-session stress is enhanced by active rest, sleep, alternation of working muscle groups in the training session, a positive psychological mental set during training and recovery, external stimulation such as massage and rub-downs, environmental stimulation from activities such as whirlpool baths and alternating hot and cold baths/showers, relaxation in flotation tanks and spa baths, and diet. Combinations of these activities accelerate recovery speeds even further. When active recovery (e.g., light runs, easy swims, a bout of surfing) is coupled with passive recovery (e.g., relaxation, warm baths, massage) the speed of recovery is better than active recovery alone (*Sports*, February 1986).

Why recovery activities are helpful is not fully understood. When light exercise is performed in the recovery periods interspersed throughout a training session, the activity facilitates the use of lactic acid as fuel by the skeletal muscles, as well as rapid circulation to the heart muscle for the same purpose. Lactic acid removal is accelerated by active recovery (Belcastro & Bonen, 1975). However, if the intensity of the effort in recovery is too high (>60 percent VO_{2max}) it is likely that more lactic acid will be produced and recovery retarded. This process explains some of the effects of active recovery both within and between training sessions.

The alternation of active and passive recovery activities is not so well understood. The following hypothesis could explain this phenomenon. When activities unrelated to the training activity or stress are undertaken, the body mobilizes many resources in much the same manner as occurs in the *Alarm Reaction Phase* of Selye's Stress Adaptation Syndrome. This exaggerated response increases the body's functions and thus accelerates the recovery process. This means that recovery acceleration should be associated with non-specific activities that challenge the body's ability to cope with them. Alternations between various stimulus modalities increase alarm-reaction-type responses even further. For example, alternations of hot and cold baths/showers, passive/active exercise, rest/massage, upright/supine postural changes, jogging/swimming, have all been found to speed up the rate of recovery from fatigue.

There is no need to restrict recovery to only one form of activity. It would seem that a variety of recovery activities of a total-body nature are better than isolated-muscle activities. It has been recommended that special recovery techniques should not be employed until 6-9 hours after either competitions or very intense training sessions (Talyshev, 1977). However, more immediate recovery activities are popular in modern sports. Research needs to be conducted to discover the most desirable timing of these procedures for swimming.

The time that an athlete has available and the activities pursued outside the training environment should be monitored. If these activities are stressful they can impede the speed of recovery. Athletes have to be taught how to behave at such times so that there is no interference with regeneration and overcompensation as they pertain to swimming. Time away from the sporting environment should be used to ensure physical and psychological regeneration before the next training session.

The point behind recovery procedures between training sessions is that a greater number of intense sessions or session elements can be completed if recovery rates are accelerated. The means by which that acceleration is promoted vary greatly and depend on the preferences of athletes for each type of activity. Specific recovery work between training sessions is now an integral part of modern sports training.

This fourth *Bulletin* discusses the training response, overload, recovery and overcompensation, and various levels and phases of fatigue. A reader might ask: "*Why such a deep and lengthy emphasis? I get it.*" The simple answer is that very few, if any, swimming coaches place much importance on recovery and the formation of training effects. The vast majority of coaches *"work"* their swimmers, with a significant proportion doing that mercilessly. The culture of traditional swimming coaching needs to change and get in step with what is known about the human response to exercise stimulation. An aim of this series of works was to make sure that someone who reads these *Bulletins* understands the importance of full recovery (recovery plus overcompensation) for improving swimming and any athletic performance. That level of understanding has to be deep so that a behavior change occurs and allows swimmers to experience frequent training effects, which is done so readily in the USRPT format. If someone does read these *Bulletins* but fails to change traditional coaching behaviors then the *Bulletins* and their author will have failed. The extensive presentations on the why and how to develop training effects that are in concert with swimming events is about as good as one could do through the printed word. USRPT is structured on purely scientific grounds and presents a method for correcting the many errors that are so evident in traditional swimming coaching.

Having read this and the previous three *Bulletins* (*60a*, *60b*, and *60c*), if the reader is not convinced that full recovery from a training segment is as important as the work performed in the segment, then I doubt if there ever will be a change to one's thinking and understanding of what sport training involves. Added to the change of elevating the importance of recovery in the practice of swimming are these additional features about the training response.

1. The activities performed in a training stimulus are the activities that will be programmed in the brain as a response to that experience. If the activities do not reflect what is required in a swimming race they will have no value for improving serious swimmers' performances. USRPT recognizes that and offers a training format that does yield valuable training experiences that transfer directly to swimming events.

2. Overloads of a particular stress-level and exercise-intensity stimulate specific-exercise improvements. The level of desirable overload is one that generates neural fatigue and to a minor extent, general fatigue in the USRPT short-work intervals. As this *"level-one"* form of fatigue is mostly recovered in a short-rest period, the amount of specifically beneficial work accumulates. Depending upon a swimmer's inherent capacities, stored oxygen is replenished, metabolites of general fatigue are mostly oxidized, and if the oxygen uptake of the work-interval is less than 2.5 liters, oxygen debt will likely be avoided (Knuttgen, 1962; Margaria, Edwards, & Dill, 1934; Schneider & Karpovich, 1948). In reality, general fatigue and oxygen debt accumulate very slowly as the repetitions in a USRPT set continue but eventually intervene at the expense of a desired performance-level. As general fatigue accumulates, neural transmissions from the brain to the working muscles are disrupted and technique errors/variants emerge. With greater psychological and physical effort the desired race-pace can be achieved for a few more repetitions but then the level of fatigue reaches a point where the standard of performance no longer can be achieved no matter how hard a swimmer tries. Recovery from USRPT sets that yield outcomes that fit those criteria will promote specific-event performance improvements.

3. Overloads that exceed the levels promoted by USRPT contribute very little to competitive performances. At most, swimmers experience a variety of technique modifications that are energized by a variety of neural and energy sources that contribute to poor propelling-efficiency. Those adaptations are mainly inappropriate for competitive performances

although they might contribute to improvements in training performances that are irrelevant for racing. Recovery from excessive fatigue generated by race-irrelevant training activities will promote a capacity to cope with a variety of fatigue situations, many of which will not occur in competitive events and settings.

Recovery from Long-term Exhaustion

The body can cope only for a limited period with adapting to excessive levels of a specific stress. Performance improvements due to specific exercise adaptations occur and then reach a plateau. If the stress of training continues, performances deteriorate rapidly, as does the ability to cope with even light amounts of the specific-exercise stress (see previous *Bulletin 60c* referring to the *"Exhaustion Phase"*). The measurement of this state is possible with the DALDA (*Daily Analyses of Life Demands of Athletes*; Rushall 1981, 1990).

Traditional swimming coaches often confuse the states of overreaching and overtraining/ maladaptation, and the Exhaustion Phase. *Overreaching* commonly occurs towards the end of a weekly microcycle. General fatigue has accrued to prevent good performances. However, overreaching is a short-lived transitory state and often is cured with 36 hours of rest after a Saturday morning unloading workout. A swimmer does not need to be in peak condition for overreaching to occur. When swimmers are conditioned as much as they can be, further heavy training can only cause the athlete to *overtrain* (excessive fatigue from specific training -- *staleness*) or to be *maladapted* (excessive fatigue from training that is not specific/beneficial to one or more race-performances). Staleness/overtraining is symptomatically similar in age-group and adult training populations (Sawamura *et al.*, 1998). Coaches who continue to stress heavy training virtually all year really are doing their swimmers a disservice. Once ceiling levels of physiological capacities are achieved, (sometimes termed the attainment of the *"athletic state"*), the only option for sane coaching is to produce specific refinements for particular events. During that altered training emphasis, the physiological conditioning of the athlete should involve *"maintenance training"* which has very different requirements and parameters to heavy/hard training. The continuation of heavy-training expectations when an athletic state is attained, would lead to performance declines associated with overtraining/maladaptation. If swimmers are given more than normal opportunities to rest and recover, performances can recover. In traditional terms, that is called *tapering*. Commonly, two weeks plus or minus a few days of reduced work volume while maintaining high-intensity work is sufficient to produce recovery. As is mentioned below, tapering does not work for about half the swimmers in a squad. Hard work programs with traditional tapers before important meets can only be tolerated by a minor subset of swimmers when a normal distribution of physical capabilities exists across a squad. For the majority of swimmers with normal to low-stress tolerance, sustained heavy/hard training pushes swimmers into an exhausted state where tapers do not work. No matter the level of motivation of a swimmer, if the basic stress-tolerance capacity is not of an almost exceptional level, improved performances at targeted important meets will not occur. Swimmers who are well into the Exhaustion Phase normally only recover when given a complete break from any training of any intensity. In the overtrained/maladapted and exhausted states, resistances to diseases are particularly low presenting a heightened health risk to the detrimentally fatigued athletes. Psychological problems also are heightened, the most common of which are questioning the value of participating in swimming, lowered concepts of self-esteem and self-worth, and reduced self-efficacy. Since more swimmers experience severe exhaustion from swimming training than not, it is worthwhile to understand the state more fully.

Traditional training has defined stages of training that lead to a peaking phase which is supposed to coincide with an important competition (Rushall & Pyke, 1991). That fatigue accrues in the latter stages of exercise stress adaptation is demonstrated by the benefits derived from reduced workloads in the tapering process (the final step in peaking) in the competition phase of training. The volume of training stimuli should be reduced prior to important competitions but the intensity maintained. The program content of such a stage is very similar to *maintenance training*. Swimmers have produced three percent improvements in performance after a 14-day tapering period in which their total volume of training decreased from 7,500 to 3,500 yards (2,250 to 1,050 meters) per day and the volume of interval work decreased from 5,500 to 1,500 yards (1,650 to 450 meters) per day. The gains in performance were associated with a significant increase in power output measured on a Biokinetic swim bench and in a power swim test. This tapering procedure had no influence on the acid-base status of blood measured after a standard-paced 200-yard swim at 90 percent maximum speed (Costill *et al.*, 1985). In tapering, the major targets for recovery are energy provision and the physiological state of the central nervous system. Case studies of international track cyclists also showed that performance benefits could be achieved by tapering. Improvements in muscular power and mechanical and cardiovascular efficiency were measured in laboratory cycling tests throughout a 4-10-day tapering period. It was also noted that mood state variables tended to alter in concert with physiological variables. For example, the cyclists became less tense and depressed and reported feeling more vigorous as the taper period progressed (Pyke, Craig, & Norton 1988).

The assumption of traditional training that is at fault is that all swimmers train hard for a set period of time, then taper, and finally compete in a championship or other targeted swim meet. The error is that all swimmers are not alike. They can train hard for a period that is governed by their inherent ability to handle the workload. If swimmers all train for the same amount of time, some will be severely exhausted by the time a taper is introduced. Havriluk (2013; also see Bulletin 60a) tested hand-force values across nine months of training. Mid-way through the hard training, one swimmer had lost ~29% of hand-force and another only ~3% of the same capacity. Upon tapering, most of those who lost a large amount of hand-force (~-13%; 4 out of 5 swimmers) failed to recover to pre-training values at the championships in spite of a taper. Those who were mostly able to tolerate the hard work for the total training period (4 out of 4 swimmers) did respond to a taper and recorded minor improvements in hand-force production after a taper. The split of improved or failed hand-strength after a taper was roughly one-half. Rushall and Ryan (1995) evaluated the success rates (improvements over entry-time) of age-group swimmers at an Australian state age-group championships. The traditional training model then was endemic across the state of New South Wales. More females failed to equal entry times than those who did (33.6%) while males fared better but still recorded more failures than successes (49.3%). Pelayo *et al.* (1996) looked at elite male 200-m freestyle swimmers over 24 weeks of training, periodically being tested over a set of 50-m repetitions and maximal 100 m and submaximal 200-m swims. There was great variation in the physiological markers taken, few of which were related to training or final championship swimming times. While anaerobic tests improved across the study, most swimmers failed to improve their times in the championship meet. The point behind this brief discussion is that at least half and usually more of traditionally trained swimmers are likely to fail in their performance standards after a taper for an important meet.

It is not the intention of this *Bulletin* to discuss tapering, although some have tried (e.g., Rushall, 1992).The mechanisms responsible for the benefits of tapering are not clearly understood but the consistent finding of improvements in muscular power suggests that neuromuscular events are involved. This supports the common observation that during periods of intensive endurance training, athletes experience a marked reduction in muscular strength and power which recovers with rest and detraining (Costill, 1998). If athletes are to perform to their full potential, it is essential that the physical stress of training be reduced in the days leading up to a competition and be non-existent on the competition day. The challenges for the coach in programming such recovery are to avoid detraining, which could happen when too much rest is scheduled, or having swimmers so exhausted that standard tapers do not allow the amount of recovery that is required for them to record an improved performance.[4]

One of the reasons for discussing the overtraining/exhaustion effect of traditional training is that it is one of the major reasons why swimmers are leaving traditional programs and turning to USRPT. Even in hybrid programs (a mix of traditional and USRPT), exhaustion still arises prominently, which prevents the benefits of USRPT being attained.

Overtraining results from overlooking the beneficial work levels of USRPT and ignoring signs of deteriorating training performances. Exposing an athlete to high-intensity stimuli over longer training distances when he or she is in a state of general fatigue accelerates the onset of exhaustion. The ability to tolerate exercise fatigue is governed by the accumulation of stresses from within and outside the pool setting. When outside stresses are increased, training loads should be reduced. Psychological demands and stresses can also hasten the onset of fatigue. Training loads must be moderated in the light of any extraneous effects.

The following is taken from Rushall (1967, pp 202-204).

> *Carlile (1960) provided two practical examples of manipulating rest and decreased workloads in overcoming the state of exhaustion. In the first example, poor performances were accompanied by all the signs of neurological and physiological strain. The second example had poor performances accompanied by no detectable signs of strain. In example one, performances were bad in all physical activities, but in the second only poor in one specific activity.*
>
> *In the first situation it was obvious that the athlete had entered well into the Exhaustion Phase. Rest and a greatly reduced workload were the methods to bring about recovery. In the general training situation, by the time a coach had recognized that an athlete had entered this phase, the athlete's deterioration was such as to warrant about a week of basic* [non-exhaustive] *work. It was best to keep some work going rather than order complete rest. Complete rest would only be used with cases of chronic fatigue. Because of individual variations between athletes, for some a week might not be long enough. The rest period should be extended until complete recovery is achieved. For young children in training, because of their quick recuperative powers, a week might be too much and a couple of days*

[4] The web site, *Coaching Science Abstracts* (http://coachsci.sdsu.edu/index.htm), contains abstracts of many researches involved with tapering.

would probably suffice. A working principle may be deemed: the younger the athlete, the less is the period required for recovery. No hard and fast principles can be entertained as to which to do to gain exact results for the treatment is extremely individual and has to be relatively "played by ear" until the coach becomes familiar with the athlete's response.

In the second situation, it was obvious that the athlete had not entered far into the Exhaustion Phase. Performance was poor at only one skill and that is suggestive that only neural fatigue existed. The remedy was to change the skills being used; for swimmers change strokes and for oarsmen change oar sides until neural recovery occurred. However, this was the first sign of approaching exhaustion and workloads should be lessened to prevent the onset of the physiological features of exhaustion.

Carlile and Carlile (1961) found that after a period of training, circulorespiratory endurance increased but swimming performances did not. That suggests some form of nervous depletion. This is substantiated by the fact that in tapering-off, performances improved because of diminished neural work and consequent recovery from fatigue before degeneration of the circulorespiratory system occurred. That is an important feature to be remembered. When resting to replenish neural functioning, measures must be taken to see that the circulorespiratory system does not lose its adaptation. This can be done by participating in activities which do not stress the already fatigued nervous patterns of the activity. Rest, reduced workloads, and adequate nutrition are three vital factors to be considered in overcoming problems of "staleness". As was pointed out earlier, it may not be that the exercise stress itself was too severe, but that additional stresses (e.g., mental strain, lack of sleep, etc.) were causing the total stress load to be too much. This alternative should not be overlooked. Eradication of some of these stresses may be sufficient to halt the onset of exhaustion. However, it is usually not until the athlete has become "stale" that the coach realizes the presence of these other stresses. Their elimination would speed recovery and they could be guarded against in future training programs. Thus, for overcoming long-term fatigue it is a trial-and-error approach, tending to be better to err on the side of too much rest than too little.

When a swimmer arrives at the exhaustion phase (i.e., an overtrained state or *staleness*) a serious error has occurred in the planning and execution of training. Unloading microcycles in the structure of macrocycles are supposed to be the insurance policy to avert long-term exhaustion. However, if overtraining does arise there are very few options for the athlete to follow in order to recover. If a stage of mild exhaustion has been reached, then extended periods of reduced volumes and non-exhaustive race-pace training with increased amounts of rest may be sufficient to allow regeneration to occur. Having the swimmer also engage in alternative activities that produce non-stressful physical demands and positive psychological states could also assist in recovery. Testing sessions and competitions should be avoided and psychological pressures reduced. With mild exhaustion it is possible that performances will recover after a relatively short time (perhaps less than one month but that is dependent on the severity of fatigue).

When a swimmer is thoroughly exhausted the prognosis is different. Then, he or she is usually required to cease training. The period of recovery is quite lengthy even though other positive-experience activities are enacted. The major recovery procedure is rest and the avoidance of any intense specific activity. The time for such recovery to occur is individual and can often be as long as six months. Performance potential deteriorates dramatically during this recovery period because of marked detraining effects. The combination of physical fatigue and its negative psychological correlates could also thwart any complete recovery. There are many anecdotal cases of athletes being severely overtrained and never regaining previous levels of performance despite reduced workloads and seemingly more sane training programs after the occurrence. If one recalls one part of the Roux Principle, *excessive training loads are harmful*, then long-term exhaustion is to be avoided at all costs. The only options for recovery are, in order of preference, rest, irrelevant activity[5], and low-intensity and low-volume specific activity.

As a means of stress control, the proportion of training time devoted to recovery, the provision of unloading steps in microcycles, and unloading microcycles in macrocycles, are all critical. The stage of exhaustion should be avoided for it has no beneficial effects for any swimmer.

Recovery and Reversibility

If recovery time is extended there is always the concern that detraining might occur. The rate at which it occurs is relevant for understanding the detrimental effects of enforced bed rest, limited movement as a result of injury, and detraining between competitive seasons.

Bed rest produces a marked deterioration in endurance performance with decreases in VO_{2max} of 6-7 percent occurring in one week and as much as 25 percent in three weeks. It then requires from four to six weeks of retraining to recover the 25 percent lost (Saltin *et al.*, 1968). A significant decrease in the endurance performance of runners has been noted after 15 days of detraining. This was particularly noticeable in the oxidative enzymes in muscle and was not recovered in the same period of retraining (Houston, Bentzen, & Larson, 1979). Costill et al., (1984) demonstrated significant reductions in the respiratory capacity of the shoulder muscles of swimmers and hence the amount of lactic acid produced in a standard speed swim, only one week after cessation of training. Brief lay-offs seemed to significantly reduce endurance performance and led to the conclusion that five months of endurance conditioning can be completely lost in 6-8 weeks of inactivity.

While muscular strength and power seem to be lost less rapidly than endurance, they are still only transient attributes (Berger, 1962). The different time courses of the rate of deterioration of muscular power and endurance perhaps explain why the taper period for a sprinter is usually longer than that of a distance runner. However, with complete immobilization in a supporting cast following bone fractures or joint reconstructions, the size and strength of the muscles can deteriorate very rapidly.

There are two implications of these findings: i) Athletes who are injured should be encouraged to maintain certain aspects of their fitness by using other limbs or modes of exercise. For example, swimmers with ankle injuries may not be able to kick but can swim with their legs trailing to maintain their central aerobic fitness and some aspects of muscular fitness. During the break between seasons, swimmers should remain active. This will allow them time to recover from the specific demands of the sport and to maintain fitness during the seasonal-transition phase. They will then enter the preparatory phase for the next competitive season at a higher level of fitness and be in a better position to make annual improvements in performance.

USRPT avoids the requirement of a traditional taper before meets (Rushall, 2014). Because USRPT stipulates training repetitions to cease when neural fatigue (i.e., an unrecoverable

[5] The irrelevant activities should be enjoyable and promote a positive outlook on life in general.

performance standard) is exhibited, swimmers are not physically depressed for long periods of time as is exhibited in traditional *"hard"* training (Havriluk, 2013). Instead of having to wait for many months before engaging in a taper (i.e., recovery from chronic physical fatigue), USRPT swimmers should be capable of performing *"peak"* races at any time after reasonable training performances are exhibited. Consequently, the use of the word *"taper"*, which has a specific meaning for traditional swimming training, is inappropriate for USRPT. *"Peaking"* is the better term for USRPT when preparing for important or specific swimming meets.

The change-training loads of USRPT are mostly less than those used in traditional swimming training. The loads of USRPT require swimmers to experience only neural fatigue, the first stage of performance fatigue from which recovery is quite quick (a matter of hours) and is not associated with overstress or overuse. That is because USRPT is self-regulating by requiring training units to cease when race-pace performance standards can no longer be sustained [the brain and the neural system no longer can adequately stimulate the required level of movement efficiency and effort associated with a particular race-pace]. That contrasts to traditional training which requires swimmers to complete the number of repetitions stipulated in a set no matter what the performance level is in the latter part of the set. That extra demand often increases the amount of lactate produced and retained in the training set and diminishes the body's glycogen stores. Lowered glycogen results in the amount of glucose available for performance to become increasingly less which is reflected in poorer performance standards. In USRPT, overtrained states are seldom displayed but when they are it is usually in a hybrid swimming program, the hybridity coming from a mix of traditional training and USRPT.

USRPT constantly monitors desirable race-relevant performances. It does not distract itself with dubious factors (e.g., lactate tolerance, aerobic adaptation, etc.) that at best are equivocally related to training responses (Montpetit *et al.*, 1981; Pyne, Lee, & Swanwick, 2001; Rowbottom *et al.*, 2001) but not related to eventual *"tapered"* race-performances. Some physiological tests performed during taper have low to moderate relationships with ensuing competitive performances[6] (Anderson *et al.*, 2003). USRPT acts as a guard against excessive fatigue and consequently, *"overuse exhaustion"* does not or rarely occurs.

Before very important competitions, it is recommended that change-training in USRPT be terminated and two stages of maintenance-training be started (Rushall, 2014). For lesser competitions, one week of peaking (maintenance) training should be implemented but two is for the most important meets. The two stages of the peaking process have different content and considerations. The first week is a partial maintenance program but the second week is a full reduction in work volume so that swimming specifically in both stroking and skills can be practiced. In the change-training phase, swimmers should be concentrating mostly on technique and a second focus would be on even race-pace training and improvements. If a coach only concentrates on physiological training, performance improvements will eventually cease. However, when technique is concentrated on as well as the physical conditioning that yields improvements in endurance at all race-paces attempted. Across the years continued improvements should be expected.

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[6] However, during taper it is too late to take any corrective steps to re-train physiological functions if those functions are important for racing but deficient in testing.

Despite the controls and safety measures that are inherent in USRPT, states of exhaustion can still occur. Some sources of the advent of overtraining/exhaustion follow.

i. Swimmers with particularly low physical stress-tolerance capacities (e.g., *"drop-dead"* sprinters) train beyond their capacities. Usually, social pressures keep such swimmers trying to train despite the rigorous dictates of USRPT. This is particularly so in situations where coaches imbue on swimmers *"guilt feelings"* for not training or unknowing parents keep pressuring the swimmer to do as much work as *"the other swimmers"*.
ii. Stresses from outside of swimming are excessive and often cannot be modified. Although the severity of those stresses might appear to be moderate, in time the accumulated affects of swimming training and those life-demands becomes excessive and the swimmer fails to adapt further. Often, reducing the demands of swimming training is insufficient to produce swimming-specific recovery. The tell-tale sign of other stresses being too high is when performances in those areas also fail (e.g., the learning of music becomes very difficult, grades at school begin to drop, problematical social interactions increase, illnesses and ailments increase in both frequency and severity).
iii. Coaches lapse back into aspects of traditional training by either running a hybrid USRPT-traditional training program where the traditional activities contradict the benefits of USRPT, or traditional training is followed for some time and then the program switches to USRPT. It should be remembered that it takes time to adapt to USRPT no matter what the traditional-fitness state of a swimmer might be (Rushall, 2013). When switching from traditional to USRPT or *vice versa*, little is gained by the swimmer in the transitional period.

If a USRPT swimmer does enter the Exhaustion Phase of training, the treatment for recovery is the same as that which is used for traditional training.

Summary

Recovery is a critical factor in modern swimming training. Coaches need to program recovery opportunities within training sessions (by planning the order and alternation of USRPT training stimuli); between sessions (by providing the opportunity to participate in active/passive recovery activities); and from overtraining. If recovery within and between training sessions is adequate and outside-of-swimming stresses minimized, then overtraining/exhaustion will likely be avoided. The Recovery Principle should be considered to be of similar importance to the Overload Principle.

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