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AN IGNORED SCIENTIFIC COMPONENT OF SPRINT SWIMMING TRAINING

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Some individuals are endowed with the ability to perform repetitive actions at an unusually fast rate. This characteristic, when coupled with the technique of applying force in the most efficient manner, produces the *"sprint"* swimmer. The following discussion concerns a factor that governs the maximization of sprinting ability in swimming. Its contents have been known for more than 30 years but have largely been ignored by coaches.

The Present Situation

In the current sprint events of swimming (competitive distances of 100 meters or less) a few features are evident. The performances of individuals are highly variable which suggests that defined, correct procedures for controlling the level of sprint performances rarely exist. There are few individuals who cluster at the top performer level. This may be interpreted as indicating that the development of this talent is by chance rather than through the design of coaching. The training programs of sprint swimming are extremely varied. Speed work commands only a minor proportion of the training load. Often the remaining time is consumed by inappropriate and performance-sapping swimming. Sprinters are often combined into the same program and group as long-distance performers. Distance training that causes fatigue suppresses the ability to sprint as it depletes a swimmer's functional strength/power. That power is only regained after sufficient restoration or a taper (Costill, 1998; Trappe, 1998).

The commonest trend in sprint training is to use only a limited form of interval training as *"speed work."* Coaches fixate on 25 or 50 meters as *"the distance"* for stimulating sprint swimming. High quality work is repeated over these distances in a rather tentative fashion because of the high level of fatigue they generate. This limited exposure to speed stimuli is further compounded by the tradition of conducting sprinting at the end of training when sprint and power production capacities are diminished. That practice is contrary to known physiological requirements of sprinting which stipulate non-fatigued states to experience maximal and appropriate adaptation because *speed improvements are primarily neural, not physiological* (Rushall, 1999b; Rushall & Pyke, 1990).

The use of interval training as the most expedient form of training for adaptation to exercise stress is widely accepted. A further principle of equal importance exists: *Training should be specific to the final desired performance.* If one wishes to perform in sprints, then training velocities should be at least the same as the speed of the final anticipated competitive performance. If there are insufficient practice trials of performing intended movement patterns then "skill" (neuromuscular patterning) will not be developed fully. Such patterns cannot be learned/developed when executed under fatigue (Williams, McEwan, Watkins, Gillespie & Boyd, 1979). The body does not have the capacity to learn movement patterns when highly stressed/fatigued. This factor is not related to the specificity of training principle associated with overload adaptation in energy systems. The specificity principle of physiological adaptation does not apply to motor learning. *To learn skilled movement patterns that are to be executed under fatigued conditions, that learning has to occur in non-fatigued states.*

If one wishes to swim 100 meters in 50 seconds then some training must be repeated at a velocity of at least 1.95 meters per second. To perform at a slower speed would result in training for a slower than desired performance. The neuromuscular patterns of performance are specific to each speed of swimming. *The skill factor in producing maximal and optimally efficient sprint performances is dependent largely upon the amount of skill executions at a specific performance velocity.* When a desired performance level requires a high velocity then one should train at that velocity to become skilled at that specific movement pattern. Unfortunately, speed work, as it is presently practiced, is so stressful that few athletes develop any great skill for sprinting. They simply do not perform sufficient trials nor experience appropriate intrinsic and extrinsic feedback to develop strong consistent sprint-movement patterns.

Swimming coaches are confronted with a perplexing problem: How can more sprint training be undertaken if it is so stressful? If a coach increases sprint training then participating swimmers will succumb more quickly to excessive stress. An obvious solution would be to strike a preference for quality (the development of specific skill) or quantity (the development of stress adaptation). However, it is possible that no dilemma should exist at all. The amalgamation of research findings of psychology and physiology suggest another alternative that allows both sprint skill and appropriate physical adaptation to be developed simultaneously.

What Science Tells Us about Sprint Swimming

The principle of specificity in exercise skill is very convincing. The integration of neural and physiological functions in a skilled motor activity is very complex and specific. For example, it is not difficult to demonstrate the complete disparity of energy and motor functioning in swimming 50 meters in 30 seconds and 32 seconds. The greater the amount of training entertained at a set speed the more predictable will be final performances. One should expect that if a sprint swimmer trained a great deal at the desired race pace then performances would be quite predictable with little variation.

Most coaches know that the energy for muscular contraction stems from three sources, aerobic and two forms of anaerobic metabolism. The liberation of aerobic energy is dependent upon oxygen being delivered to the working muscles via the cardiovascular system. However, in brief spurts of very intense activity the supply of aerobic energy is very inadequate. Most of the energy for sprint swimming is acquired from anaerobic sources. This produces the phenomenon of *"accumulated oxygen deficit"*. Few coaches realize that there are two anaerobic energy sources within the muscles. The alactacid energy system is functional only over the first 10 and possibly up to 15 seconds of maximum swimming effort as it uses existing energy sources that reside in the muscles. This energy source is restored within seconds over an ensuing rest period. There is no accumulation of lactate. This duration is longer than is commonly espoused because not all the swimming repetition involves swimming strokes, the push-off from the wall consuming more than two seconds. As well, the muscles of the upper body are particularly endowed with Type II muscle fibers and so can perform anaerobic functions quite well. If the period of intense work is greater than 15 seconds the functional limit of alactacid energy source will very likely be surpassed. The second source of anaerobic energy, the lactacid energy system (glycolysis), provides most of the energy for the additional period of muscular contraction beyond 15 seconds if the original pace is maintained. It should be noted that in this paper time estimates overlap and that is deliberate. The employment of energy systems is not discrete but rather unified and it is only the emphasis of their use that discriminates their function over time. Glycolysis produces lactic acid. In prolonged use it results in the accumulation of lactate, extreme muscle fatigue, and the depletion of glycogen stores. Because of the duration and distances used, present forms of sprint training employ both anaerobic energy sources resulting in high levels of fatigue and few trials of velocity-specific neuromuscular patterns.

Research on Short Work Intervals

Astrand and Rodahl (1977) related research findings that have been known since the late 1950s. If the work duration is short enough, even though intensity is very high and if recovery periods are short, energy sustains mechanically efficient *"fast"* work while no buildup of lactate occurs. As well, glycogen levels remain high throughout the short intervals whereas with longer intervals they depreciate significantly. Figure 1 displays results of a study where in a 30-minute period of cycling, subjects performed the same total workload with the same work to rest ratio in three different ways: 60 s / 120 s, 30 s / 60 s, and 10 s / 20 s. In the shortest work interval, blood lactate did not accumulate and glycogen stores were only slightly reduced by the end of the session. At the other extreme the longest interval produced excessive lactate accumulation and glycogen depletion. The middle condition produced an elevated but consistent lactate accumulation.

A sustained presence of readily available glycogen is essential for skilled (neuromuscular) function. It allows an athlete to practice the neuromuscular patterns associated with high rates of quality performance without disruption for it is known that as lactate accumulates beyond a certain level (a rough estimate is >4 mM), neuromuscular functioning is increasingly disturbed. Consequently, hard/extended sprinting that accumulates lactate does not accommodate learning the skilled movement patterns associated with sprinting. Another benefit from very short interval training is that recovery is rapid and is significantly shorter than that required for accumulated-lactate work bouts. In swimming that facilitates an increased number of executions of skill cycles. Exercises that use work and rest intervals with these characteristics have been labeled *"ultra-short training"* (Rushall, 1970).

Tabata et al (1997) demonstrated that two disparate energy systems could adapt during the same exercise. One protocol involved 6-7 bouts of 20-s exercise with 10-s rest at an intensity equivalent to 170% of VO2max. The other protocol involved 4-5 bouts of 30-s exercise with 2-min rest at an intensity equivalent to 200% VO2max. It was found that physiological factors deteriorated in the last 10 s of the longer repetitions. The shorter interval taxed aerobic and anaerobic energy maximally. This investigation suggests that the duration of a work interval must be sufficient to employ maximal energy supply but should be short enough to prevent performance and physiological degradation.

Since swimming is a cyclic activity that does not use the total body musculature, is supported and cooled efficiently by water the rest periods do not need to be as long as in the cycling study. Practical experiences have shown that a one to one work to rest ratio are satisfactory for swimming.

Energy use in ultra-short training

The energy that is used throughout an ultra-short interval set of a high number of trials changes from the early to late stages within the set and with training.

- Early in a set, energy that exists within the muscles is primarily used, alactacid sources being exploited more than lactacid sources. Aerobic energy is gradually stimulated into action and increases its function with each successive trial. As the set progresses, alactacid energy is still employed. Type II (fast-twitch glycolytic) fibers are continually stimulated along with Type I (slow-twitch oxidative) fibers. Some glycolysis does occur but not in amounts that lead to any significant lactate accumulation. The amount of oxidative work at the end of an ultra-short set is greater than at the start while swimming speed remains the same.
- As ultra-short intervals are employed consistently in practices, some Type IIa fibers (low-oxidative or glycolytic fibers) eventually are converted to Type IIb fibers that become oxidative while still maintaining their fast-twitch contractile function. With adaptation of these fibers, work earlier in a set is more oxidative than in an untrained state. That means more sprint work is "fueled" by oxygen rather than lactate-producing anaerobiosis. The capacity for producing work through the alactacid energy system is increased although only by about 2-3 seconds duration. There still is some requirement for glycolytic work. The frequent but mild stimulation involved in the very short repetitions produces some adaptation although that improvement might not be as great as that experienced in heavy sprint sets where lactate accumulates to high levels.

- Consistent ultra-short training produces sprinting performances that sustain fast-twitch (Type IIb) fiber use but energize performance with greater amounts of oxygen. This extends the ability to sustain a sprint with good mechanical function. Eventually, glycolytic anaerobic function is also improved. The mild stimulation of ultra-short training eventually does produce levels glycolysis adaptation over and above those achieved by severe stimulation from heavy sprinting. When heavy sprint sets are experienced, swimmers often enter an overtrained state before maximal adaptation is achieved. However, while the milder ultra-short work does not produce as rapid lactacid adaptation, it eventually does produce higher levels of glycolytic adaptation and consequently produces further performance improvements.

Ultra-short training develops alactacid energy production, fast-twitch oxidative and fast-twitch glycolytic function, and aerobic adaptation, all while executing race-specific motor skill patterns. These outcomes facilitate better sprint performances than those fostered by typical, and mostly inappropriate, sprint training for swimming.

IMPLICATIONS FOR SPRINT-SWIMMING TRAINING

Research comparing very short (10 seconds or less) to longer (30 seconds or more) work intervals has shown the latter to be extremely fatiguing. Even the best swimmers should not repeat workouts of 50-m sprints more than three times a week. Failing adaptation is observed if this is carried out over an extended period of time (often within two months). On the other hand, this need not occur if shorter work intervals are utilized.

It is possible to do more sprint swimming training without the problematic fatigue effects of typical programs. The utilization of *"ultra-short repeats"* produces all the benefits of desirable sprint training and adds some exciting new advantages. It behooves the coach to work with swimmers to find the interval distances in which repeated performances will be at least equated to desired performances. To be on the safe side, the work period should be in the vicinity of 10 seconds. Thus, distances of less than 20 meters will become important training units for sprinters. For example, a female 100-meter butterfly swimmer who aims at a time of 64.0 seconds must repeat 12.5 meters in 8.0 seconds. A procedure of 4 sets of 40 x 12.5 meters with 8 to 10 seconds rest between each repeat would be quite feasible. Most pool widths would be suitable for this form of training. The implication of this format for training is clear. The more training that can be accomplished at the pace of the desired performance the better will be the final performance.

A reluctance to remove lane lines that would allow swimming across the pool is not an acceptable excuse for not using desirable distance and time periods for sprint training.

Table 1 compares ultra-short repeats with normal sprint training. Some of the main features and advantages of the proposed form of training are listed below.

1. A greater number of strokes are executed in a standard period of time.

2. A greater amount of work is performed in a standard period of time.
3. It is probable that ultra-short repeats can be used each training day irrespective of the seasonal training period.
4. Greater swimming skill at sprint speed is attained.
5. Greater anaerobic adaptation is attained.
6. Aerobic adaptation is stimulated.
7. Fatigue levels are tolerable.

TABLE 1. CHARACTERISTICS AND QUALITATIVE COMPARISONS OF TWO FORMS OF SPRINT TRAINING FOR SWIMMING

	Duration of work less than 15 seconds	**Duration of Work 15 seconds or more**
Work to rest ratio	1:1	1:3-5
Rest interval	Less than 15 seconds	One minute or more
Practice time allocated	30 minutes	30 minutes
Time spent swimming	15 minutes	5 minutes
Number of repetitions	90	20
Number of crawl strokes/interval	8	16
Number of crawl strokes/set	720	320
Frequency of use	Possibly each day	Two to three times per week
Period of use	Possibly for full season	Specific training phase
Skill training effects	Competitive skill and speed maintained for set	Speed and skill deteriorates as set progresses
Conditioning effects	Aerobic, alactacid, and minor lactacid adaptation; functional strength	Aerobic, lesser alactacid and lactacid adaptation; some functional strength
Fatigue per set	Moderate to heavy at end; moderately stressful but capable of sustained used with proper diet and rest	Maximal half way through; extremely stressful; glycogen depletion; not appropriate for sustained use; could produce chronic fatigue

Recovery	Aerobic nature allows quick recovery	Slow recovery dependent on glycogen replenishment
Swimmer behavior	Race speed sustained, technique maintained	Maximum effort, speed and technique deteriorate
Swimmer behavior at end of set	Tired but can continue with practice	Fatigued; not likely to perform any more practice items well

The benefits of the ultra-short system are highly desirable. Its characteristics and qualities have been validated in the laboratory. It now remains for coaches to employ this model for training. In a brief test over a four-week period, a girl butterfly swimmer was able to tolerate two sets of 40 x 12.5 yards in 6.5 seconds with 7 seconds rest, five days per week without any apparent failing adaptation. However, much more field-testing is warranted.

Ultra-short interval training in swimming

This form of training is based on the principle that sufficiently short intervals of intense work do not produce lactate accumulation. It is appropriate for developing alactacid and aerobic endurance at the same time and provides the opportunity for specific skill training at competition intensity. It is appropriate for training phases where specific training is important. When short work bouts are alternated with short rest periods, it is possible to complete a large amount of training at competition quality. For example a 1:1 work/recovery ratio of periods totaling 10-15 seconds can be sustained in trained age-group swimmers at 200-m competition quality for at least 30 minutes. However, when the same work/recovery ratio is maintained but the duration of the task is increased to 20+ seconds, performance deteriorates quite noticeably and work cannot continue for 30 minutes. Ultra-short intervals do not produce lactate accumulation. It is when lactate accumulates that fatigue becomes devastating and adequate recovery then takes a markedly greater proportion of time (Rushall, 1999b).

Examples of ultra-short training stimuli for swimmers are:

Repetitions	Distance	Stroke	Intensity	Recovery	Recovery activity
20 x	Across pool (20 m)	Butterfly	100-m race pace	Remainder of 20-25 sec interval	Float
20 x	Across pool (20 m)	Backstroke	100-m race pace	Remainder of 20-25 sec interval	Float

In these examples, the swimmer starts every repetition on a 20-25-second interval, the rest period being that time remaining from 25 seconds after each effort.

The selection of a 20 or 25-second total interval depends upon the standard of the swimmer. The younger the swimmer, the shorter should be the work interval and consequently, the rest interval. Prepubescent swimmers most likely will repeat over distances of 15 meters or less in a time period of less than 10 seconds. For senior swimmers it is possible that a 25-yard pool could provide the upper end distance over which ultra-short training can be practiced.

Closure

This paper proposes that effective sprint training must involve conditions that allow the movement patterns, that is the skill, of swimming at high velocities to develop. Current coaching practices do not facilitate the development of these patterns nor do they maximally adapt the appropriate energy structures that should be associated with sprinting in swimming races. Ultra-short interval training is promoted as being the form of programming that corrects these two deficiencies.

The application of ultra-short training must be within reason. One should not assert a desired race time that is impossible for the performer to achieve. Making the training load too stressful (e.g., the work period is greater 15 seconds; insufficient recovery and rest periods) would also violate its use. Variety can be introduced into the program by swimming different strokes and distances. The main role of the coach is to ensure that the speeds of swimming are maintained and technique features are emphasized.

The message from this discussion is quite simple. Sprint swimming events will be performed better if more training can be accomplished at race pace. A method for doing this has been described. The three main characteristics of that method are:

1. the work period should be less than 15 seconds,
2. the speed of swimming should be equivalent to that of a desired sprint performance, and
3. a sufficient number of repetitions in a set should be performed to produce skill learning and energy system adaptations.

The scheduling of this training form should be at the start of a training session before any fatigue is experienced or other serious training is performed. This form of training should be the major component of sprint swimming training.

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ABSTRACTS OF THREE STUDIES THAT SUPPORT THE USE OF ULTRA-SHORT TRAINING

1. AN EVALUATION OF THE BENEFITS OF ULTRA-SHORT WORK INTERVALS

Astrand, I., Astrand, P-O., Christensen, E. H., & Hedman, R. (1960). Intermittent muscular work. ***Acta Physiologica Scandinavica, 48,*** 448-453.

A well-conditioned male performed several one-hour bouts of cycle ergometry producing a constant work output of 64,800 kpm. Each exercise consisted of alternating work and rests of .5, 1, 2, or 3 minutes. Continuous work for one hour at half-the intensity was also performed.

It was found that the heavy work was transformed into a submaximal load on respiration and circulation with the shorter work periods of .5 and 1 minute.

Mechanical efficiency was highest in the easier continuous work. Among the intermittent experiences, the shorter time periods, and in particular the .5 minute work/rest alternation, yielded the highest efficiency. As the interval of intermittent work increased, mechanical efficiency decreased.

Work with the short periods (.5 and 1 minute) was perceived to be relatively light, and no significant fatigue was experienced in the one-hour. Work at two, and especially three minutes, produced an exhausting maximal load.

The most surprising result was the low lactate values at the .5 minute work, less than half that achieved with 1-minute work, and much less than at the remaining two longer work periods.

The significant implication of this study was that a great amount of heavy work can be performed with a submaximal load on circulation and respiration by a suitable application of short work and rest periods. Large muscle groups can be trained without simultaneously loading the respiratory and circulatory organs. The term for this form of training is *"ultra-short training."*

Thus, it is possible to effectively train full-effort, large-muscle activities while enjoying circulatory and respiratory (aerobic) training effects similar to those achieved with continuous activities performed at a much lower level of intensity. This should be a superior form of training to the more established, but less beneficial, forms that still pervade most sports. This investigation showed clearly, that hard exercise of an extended interval nature does not yield the best training response.

Implication. Ultra-short training produces aerobic and alactacid energy training effects, as well as competition-specific neuromuscular training effects. It is possibly, the best form of training for individuals who have to compete at heavy workloads for extended periods.

2. ULTRA-SHORT TRAINING DEVELOPS THE AEROBIC COMPONENT OF HIGH-INTENSITY WORK

Christensen, E. H., Hedman, R., & Saltin, B. (1960). Intermittent and continuous running. ***Acta Physiologica Scandinavica, 50,*** 269-286.

The physiological responses of two males to running at 20 km/h on a horizontal treadmill were investigated. Work and rest periods from 5 to 15 seconds in various combinations for a total period of 30 minutes were preformed. A continuous run at the selected pace was also investigated.

Both Ss responded differently to the conditions. One S had less work capacity than the other requiring *"lighter"* workloads to avoid detrimental fatigue. This observation confirmed the need to individualize training programs if all participants are to receive the best effects from training experiences.

Both Ss reached oxygen uptakes during intermittent running close to or equal to their maximum. For one S the work to rest ratio of 15 seconds to 15 seconds, and for the other 10 seconds to 5 seconds, produced the maximal response.

Several relationships were found among the iterations of duration, distance, and work:rest ratios.

- If total training distance is increased then work periods should be decreased, or the work:rest ratios increased, otherwise lactate will increase.
- For shorter work periods, lactate accumulates for the first five minutes and then levels off, that level increasing as the work period is extended. However, at some point when increasing work periods, lactate accumulation does not level off, indicating excessive work and stress.
- As work:rest ratios are decreased, the period of work should also be decreased otherwise the stress of training (lactate levels) will become excessive.

For both Ss at this running velocity, work periods of 15 seconds were excessive, while 5 and 10 seconds were not.

Under continuous running at 20 km/h, one S could only continue for 3 minutes while the other performed for 4 minutes. The amount of work performed, and therefore the potential to gain benefits from training, became less as the duration of work and accumulation of anaerobic metabolites increased.

With short work and rest intervals, it is possible to perform a substantial volume of high-intensity work supported by primarily aerobic metabolism.

"Two physically trained subjects can run continuously for 3 or 4 minutes respectively on a treadmill at a speed of 20 km/h, reaching maximal values for oxygen uptake and for blood lactic acid. At the end of this time when they have run a total distance 1 and 1.3 km respectively, they will be totally exhausted and will need a comparatively long time for recovery. Running at the same speed, but intermittent with short spells of activity and rest, the character of work will change entirely; despite a marked decrease in oxygen uptake during the actual work periods, the work can be performed without or with only a comparatively slight increase in blood lactic acid concentration, indicating aerobic or practically aerobic work conditions. The trained subjects can stand an effective work time of 15 or 20 minutes respectively, within the experimental time of 30 minutes, and run a total distance of 5 or 6.67 km respectively, without being totally exhausted." (p. 286)

Implications. Several guidelines for planning effective training programs are inherent in this study.

- Training that is exhausting is not necessarily the best or even effective stimulus. Training work volumes decrease with high-intensity work periods of 15 seconds or more at work:rest ratios of 1:1 up to 1:3, and are least when performed as a single continuous work effort.
- It is possible to perform a large volume of high-intensity work by using work and rest periods of 5 or 10 seconds, normally in a 1:1 work:rest ratio.
- As high-intensity work periods extend to 15 seconds and beyond, the requirement for longer rest periods increases disproportionately.

- Intermittent work (*"ultra-short"* work) of the type explored in this investigation, is the training regime that will allow the volume of high-intensity or competition-specific work to be increased.
- Intermittent work of this type is the only form of training that effectively trains the aerobic component of work at high-intensity.
- The responses to intermittent work are individual. While the work interval (e.g., 10 seconds) might seem to be very short, it could still be too much for some athletes.

3. ULTRA-SHORT TRAINING, NOT LACTATE TOLERANCE TRAINING, IS THE BEST FORM OF WORK FOR HIGH EFFORT TRAINING

Christensen, E. H. (1962). Speed of work. ***Ergonomics, 5,*** 7-13.

A large amount of research in exercise physiology has focused on aerobic endurance. Much less has emphasized heavy or moderately heavy work. Every increase in workload demands more oxygen, which in turn increases the load on respiration, circulation, and heat regulation. Training athletes by having them experience very high physiological stress for *"long"* periods, limits eventual adaptation and produces fatigue of sufficiently high levels and lasting effects that subsequent training is disrupted. Such work actually reduces the amount of effective training rather than being an effective way of improving ultimate performance.

The major confounding factor with prescribing training loads is individual variations in work capacity. While norms and tables that indicate ranges are produced, they do not satisfy any need for individual exercise prescription. Most of all, such general guidelines do not accommodate individual variations in how effort is distributed most efficiently over a long bout of heavy work.

A great quantity of heavy muscular work can be performed if it is performed as many short work and rest periods. This produces a submaximal load on circulation and respiration and allows training volume to be significantly greater than if work is performed for longer periods. Respiratory and circulatory stress and lactate accumulation, features of debilitating training fatigue for athletes, are avoided with ultra-short training.

The reason ultra-short training works on developing aerobic endurance is that it taxes endurance development in the periphery (in the muscles). It uses as its primary oxygen source, oxygen stored in the muscles and circulating in the blood. Over and over again, these oxygen sources are depleted and replenished causing these mechanisms of oxygen delivery to be stimulated maximally. They are stimulated much more in ultra-short training than in continuous work (where the intensity of work is lower and/or non-specific). Ultra-short work appears to be the only way maximal stimulation of this important feature of aerobic adaptation occurs, possibly because of the volume of exercise accomplished. The added factor of this adaptation occurring with neuromuscularly correct exercises is one more justification for its use. Ultra-short training is the best way of stimulating aerobic adaptation in the periphery while not overtaxing the central mechanisms (respiration, circulation, heat generation) of aerobic work.

High-effort-level sporting event-specific training can be performed using very short work bursts and brief rests. Not only is the total volume of work increased, but so is the volume of specific high-intensity work-quality maintained. Neuromuscular patterning of a competition-specific nature can be enhanced.

This work puts to rest the claim that sport training, which produces high levels of fatigue with high levels of lactate, is a *"good"* training experience. Such training is often called *"lactate tolerance"* training. It reduces the volume and quality of potentially beneficial training that could be performed, and therefore, should be viewed as detrimental to possible adaptation, certainly when compared to what can be achieved with ultra-short training.

Implication. Ultra-short training, rather than lactate-tolerance training, is the better method for developing performance improvements in heavy work or high intensity sporting events.