

# STROKEARCS

The Newsletter of the Association of Rowing Coaches, South Africa

No 28 July 2008

## TABLE OF CONTENTS

<b>Training – The Importance of Training Volume for Elite Rowing Performance</b> .....	2
<i>From Filipe Salbany</i>	
<b>Creating Training Programs – Spracklen's Notes – Part 1 – Program Outline</b> .....	5
<i>By Mike Spracklen October 1987</i>	
<b>Strength Training – The Safety of Free Weights</b> .....	8
<i>By Dr Fred Hatfield From <a href="http://www.drqsquat.com">www.drqsquat.com</a></i>	
<b>Recovery – Restoration and Regeneration as Essential Components within Training Programs</b> .....	9
<i>From <a href="http://www.swimmingcoach.org/articles/9712/article5.htm">http://www.swimmingcoach.org/articles/9712/article5.htm</a> By Angie Calder, B.A., M.A. (Hons), B. Appl. Sci. Sp.</i>	
<b>Physiology – Heat Acclimatization</b> .....	14
<i>By Lawrence E. Armstrong, Ph.D. From Armstrong, L.E. (1998). Heat acclimatization. In: Encyclopedia of Sports Medicine and Science, T.D.Fahey (Editor). Internet Society for Sport Science: <a href="http://sportsoci.org">http://sportsoci.org</a> 10 March 1998.</i>	
<b>Training – Components of a Training System</b> .....	18
<i>From Periodization: Theory and Methodology of Training By Tudor Bompa</i>	
All articles available online at <a href="http://www.arcrsa.blogspot.com">www.arcrsa.blogspot.com</a>	



# ROWING TRAINING

## THE IMPORTANCE OF TRAINING VOLUME FOR ELITE ROWING PERFORMANCE

Nothing will have a bigger impact on an individual's chances of achieving an elite level of rowing performance than following a well-designed training program. Only through appropriate training can aspiring rowers develop the outstanding levels of conditioning and technique necessary for success at an elite level. However, it is a major challenge to understand the specific and often complex effects of a particular type of training on the body. Consequently, many "potential" elite rowers fail to make the transition from a national to an international standard because they adhered to a generalized training program that was not appropriately tailored to meet their individual needs. Coaches can avoid this situation by carefully examining the training practices of successful elite rowers and developing an understanding of how the body responds to different forms of training. In doing so, coaches should be able to create appropriate and individualized programs for their own athletes. Since the first challenge in preparing a training program is to decide the amount of actual rowing required each week, this article examines the relationship between weekly volume of rowing and the anticipated changes in physiology and performance.

### Current training practice

Typically, elite rowers will cover in excess of 4300 miles of rowing per year (an average of 90+ miles/week) in addition to land based training [13]. The months of September and October are traditionally the starting points of the training year in the northern hemisphere. During this first part of the season, the primary aim is to increase the endurance capacity of the body. Training consists of specific (boat work) and non-specific activities (rowing ergometer, resistance work, flexibility, running, cycling etc...). Accordingly, the total amount of rowing during the first month(s) may be somewhat low to moderate (30-70 miles/week) in order to accommodate non-specific activities and allow the body a chance to re-adjust to the demands of training. Each week, total rowing distance can be progressively increased until the desired volume is achieved (see Figure). Predictably, the average exercise intensity of pre-season training should be low to moderate (mostly UT2 and UT1), which reduces the injury risk from overstress of muscles and connective tissue and give athletes a chance to concentrate on technique. More importantly, low intensity training enables athletes to complete a much higher volume of work than would otherwise be possible with higher intensity exercise [16]. Even several months into the season, the average intensity of training is still low, although some higher intensity work in the form of long intervals and head-races is often included. It should be recognized that while relative training intensity (i.e. % of max heart rate

or blood lactate levels) remains low, the absolute intensity (i.e. boat speed) naturally increases with improvements in fitness and technical ability. Classical training theory for rowing suggests that the volume of training should be greatest in the period preceding the main competitive season (December to May, see Figure) [1]. This strategy minimizes the potential for excessive volume to interfere with the quality of high intensity training later in the season. While the classical pattern of volume change is apparent in the seasonal training program of many elite rowers [1, 17], other factors such as climate, hours of daylight and participation in training camps often result in maximum training volumes occurring later in the season [3, 13]. Training intensity will be highest during the competitive season (June-September) although inevitably, the total volume of training, regardless of intensity, must be reduced towards the end of the season to allow athletes a period of full recovery before final competition.

### Effects of high volume training on aerobic capacity and endurance capacity

All too often, the terms aerobic capacity and endurance capacity are used synonymously. However, aerobic capacity indicates the maximum rate at which energy is made available to the muscles using oxygen, whereas, endurance capacity indicates the ability to maintain a particular rate of energy use. Hence, aerobic capacity is a measure of how fast a person can go, whereas endurance capacity indicates how far they can go<sup>1</sup>. Different types of training sessions can improve aerobic capacity without altering endurance capacity and vice versa. So, which is more important for rowing performance?

Changes in the physiology of elite rowers before, during and after a season or more of training have been extensively detailed in several excellent scientific reports [5, 6, 16]. From these studies, it is clear that the ability to develop a high aerobic capacity through appropriate training is critical to achieving success as an elite rower. Indeed, a high aerobic capacity appears to be the single most outstanding physiological feature of top rowers [4].

Rowers with high aerobic capacities are able to generate greater amounts of energy before experiencing the fatigue-inducing side effects associated with anaerobic energy use. All else being equal, rowers with high aerobic capacities outperform those with lesser abilities to use oxygen. Although genetic endowment sets the upper limit to improvement, individuals cannot reach their true aerobic capacities without first completing several years of well-structured training. This raises the question as to the appropriateness of high volume training for maximizing improvements in aerobic capacity.

Results from studies of elite rowers in Eastern Europe suggest that aerobic capacity does not appear to improve once annual training volume reaches ~3500

<sup>1</sup> Assuming anaerobic capacity, technique and energy stores are equal etc...

miles/year (~70 miles week). It should be noted that the vast majority of their training was performed at low relative intensities (UT2 and UT1). As mentioned earlier, increases in training volume necessarily reduce the overall exercise intensity. However, there is substantial scientific evidence to show that exercise intensity rather than volume is the primary factor that controls improvements in aerobic capacity [4, 6, 8, 10, 18]. The experience of elite Eastern European rowers also suggests that there is a limit to the benefit of increasing training volume for improving aerobic capacity. Collectively, it is reasonable to conclude that maximum aerobic fitness can only be achieved through the appropriate use of strenuous high-intensity interval sessions. Why then might the high volumes of low intensity training currently performed by elite rowers provide benefits in terms of the physiological requirements for success over 2000-m?

The primary effect of high volume training on the body is to increase the endurance capacity of the muscles. Large quantities of distance training alter the function and structure of the muscles recruited during the rowing stroke in a variety of ways, too numerous to list, but all linked by a common theme: High volume training improves the ability of muscles to store and use energy efficiently.

Most coaches and rowers now recognize the importance of the body's carbohydrate levels on endurance capacity.

Although the exercising muscles can use both fat and carbohydrate as a fuel source, only

carbohydrate can supply energy fast enough to allow rowers to work at anything above low intensity rowing. In the absence of dehydration and/or high ambient temperatures, the failure to continue moderate intensity exercise is most frequently due to an exhaustion of available carbohydrate stores. Additionally, the ability to perform high intensity interval training is severely reduced if carbohydrate stores are low [14].

Fortunately, muscles respond to high volume training by:

- Increasing the capacity to store carbohydrate
- Preferentially increasing the relative contribution of fat as a fuel source during exercise.



While the adaptations that occur with high volume training are responsible for significant improvements in endurance capacity, they do little to directly improve aerobic capacity. Nevertheless, the changes described above will enable rowers to train harder, longer and more frequently. Since exercise intensity is the critical stimulus for maximizing improvements in aerobic capacity, an improved endurance capacity will increase the ability of rowers to sustain high intensity exercise during strenuous interval sessions, thus ensuring that the body receives the maximum possible stimulus for adaptation. Therefore, the gains that can be made in aerobic capacity later in the season will largely depend upon the extent to which muscular endurance capacity was developed in the early months of training. This

same line of reasoning can be extended to include other physiological components necessary for success such as anaerobic capacity.

### How much volume is necessary?

Presently, the available scientific evidence does not indicate the precise range in average weekly volume that should be performed at each training phase. Additionally, it is difficult to obtain a clear picture of the benefits of elite training patterns since many successful coaches prefer to remain secretive about the specific details of their training schedules. However, German scientists have reported that, as a general rule, their rowers no longer perform the extremely high volumes of specific rowing training that were common in the past (>120 miles/week) [15]. Instead, more time is now dedicated to non-specific training activities. More recent reports on the training practices of elite Norwegian and Italian rowers reveal a more

reasonable average of ~100 miles/week, with a range of between 60 and 130 miles in any given week. A similar trend toward lower overall training volumes in recent years has been reported for elite cyclists and distance runners [9, 12].

In contrast to rowing, there is a substantial amount of information available on the training practices of the world's best distance runners. While many elite distance runners are able to compete successfully on comparatively low training volumes (approximately 40-60 miles/week) [11], several expert coaches and scientists believe that the ultimate level of competitive performance achieved with such training will be restricted [7]. Measurable improvements in the physiology of distance runners using available scientific

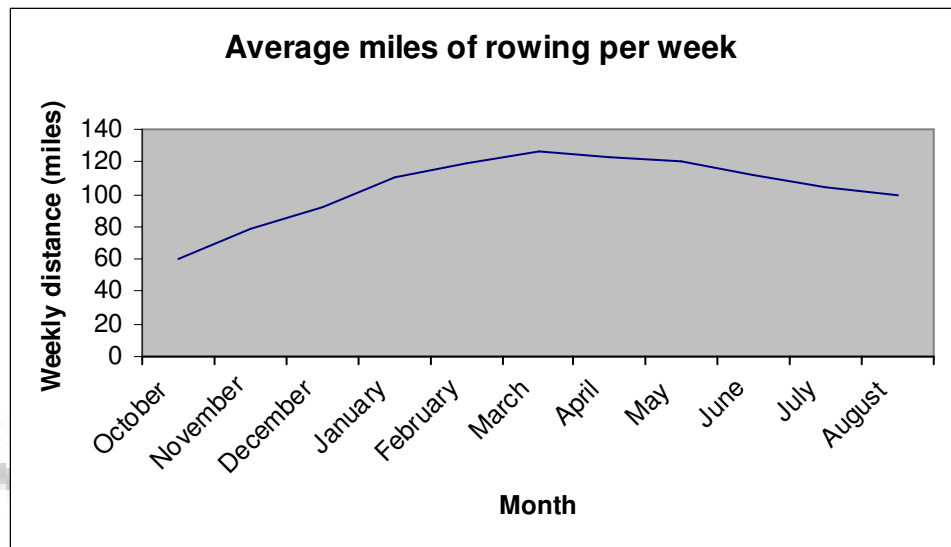
techniques (e.g., aerobic capacity and lactate threshold tests, muscle biopsies etc.) appear to plateau at a weekly volume of around 80-90 miles [2]. Higher volumes of running than these are often justified through subtle but important enhancements in running economy/efficiency that are potentially too small for scientific tests to detect.

performance and overtraining. In order to provide athletes with the greatest possible chance of success, coaches must first develop a comprehensive understanding of the effects of training and decide on the most appropriate course of action for each individual.

Based on the limited data available for rowers, it appears reasonable to suggest that the “apparent” maximum and direct physiological benefits of rowing training occur at a volume of between 70 and 100 miles/week. Nevertheless, the experience of today’s top rowers suggests that it is possible to perform even greater volumes of training without any obvious deterioration in long term rowing performance. As discussed above, this may be due to the importance of developing a superior endurance capacity for performing high intensity training later in the season. On the other hand, the true benefit of high volume training may have more to do with technical, rather than physiological changes.

One of the major differences between rowing and other endurance sports such as cycling and running is the importance of higher levels of technical skill in rowing to ensure optimal transfer of energy into boat movement. Potentially, high volume training enhances the efficiency of the rowing stroke. Certainly, improvements in efficiency during simulated rowing exercise have been shown to occur in response to additional years of training in American oarsmen [5]. While improvements in stroke efficiency of an individual are probably due to better posture, blade work and coordination between muscle groups, there is also evidence emerging to show that the manner in which the brain activates individual fibers responds favorably to extensive endurance training. Additional research is needed before high volume training can be justified based on improvements in stroke technique and efficiency.

There are various other possible reasons why high volume training is important for rowing performance. It may be that this type of training particularly helps increase focus and determination in athletes. Additionally, lightweight rowers will benefit from the increased energy expenditure that will help control body fat levels. However, unaccustomed and rapid increases in training volume will inevitably result in illness, injury and reduced performance. Coaches must weigh up the potential benefits of high volume training with an athlete’s training history, ability and goals. Additionally, coaches need to resist the temptation to continually prescribe higher and higher annual training volumes. There is an obvious upper limit to the advantages of increasing total volume. Eventually, sustained high volumes will lead to stagnation of



*Hypothetical variation in training volume of an elite rower during a season*

1. Bompa, T.O., *Periodization: Theory and methodology of training*. 1994, Leeds: Human Kinetics. 1-413.
2. Costill, D.L., *Inside Running*. 1986, Human Kinetics: Champaign, IL.
3. Cracknell, J., *Revenge mission*, in *The Daily Telegraph*. 2002: London. p. S5.
4. Dudley, G.A., W.H. Abraham, and R.L. Terjung, Influence of exercise intensity and duration on biochemical adaptations in skeletal muscle. *Journal of Applied Physiology*, 1982. 53(4): p. 844-850.
5. Hagerman, F.C., Physiology and nutrition for rowing, in *Perspectives in Exercise Science and Sports Medicine*, D.R. Lamb and H.G. Knuttgen, Editors. 1994, Cooper: Carmel, IN. p. 221-302.
6. Hagerman, F.C. and R.S. Staron, Seasonal variables among physiological variables in elite oarsmen. *Can J Appl Sport Sci*, 1983. 8(3): p. 143-8.
7. Hawley, J. and L. Burke, *Peak performance: training and nutritional strategies for sport*. 1998, Sydney: Allen & Unwin. 1-446.
8. Hickson, R.C., H.A. Bomze, and J.O. Holloszy, Linear increase in aerobic power induced by a strenuous program of endurance exercise. *Journal of Applied Physiology*, 1977. 42(3): p. 372-376.
9. Jeukendrup, A.E., *High Performance Cycling*. 2002, Leeds: Human Kinetics.
10. Mahler, D.A., H.W. Parker, and D.C. Andresen, *Physiologic changes in rowing*

performance associated with training in collegiate women rowers. International Journal of Sports Medicine, 1985. 6(4): p. 229-33.

11. Martin, D.E. and P.N. Coe, Training distance runners. 1991, Leeds: Human Kinetics.
12. Maughan, R.J., Physiology and nutrition for middle distance and long distance running, in Perspectives in Exercise Science and Sports Medicine, D.R. Lamb and H.G. Knuttgen, Editors. 1994, Cooper: Carmel, IN. p. 329-371.
13. Secher, N.H., Physiological and biomechanical aspects of rowing. Implications for training. Sports Med, 1993. 15(1): p. 24-42.
14. Simonsen, J.C., et al., Dietary carbohydrate, muscle glycogen, and power output during rowing training. Journal of Applied Physiology, 1991. 70(4): p. 1500-5.
15. Steinacker, J.M., Physiological aspects of training in rowing. FISA Coach, 1994. 5(3): p. 1-6.
16. Steinacker, J.M., et al., Training of rowers before world championships. Medicine & Science in Sports & Exercise, 1998. 30(7): p. 1158-63.
17. Vermulst, L.J., et al., Analysis of seasonal training volume and working capacity in elite female rowers. International Journal of Sports Medicine, 1991. 12(6): p. 567-72.
18. Wenger, H.A. and G.J. Bell, The interactions of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. Sports Medicine, 1986. 3: p. 346-356.



rowing world, but they have been adapted to encourage the improvement of technique in such a way that technical progress is an important part of the System.

The System originated from the concept that technique should play a bigger part in the preparation of oarsmen for racing. One benefit to be gained from the principle of this System of training is that the drudgeries of winter training become purposeful. The oarsmen become distracted from the hard work they are doing without realizing it!

Mike Spracklen.  
October 1987

### TECHNIQUE

An efficient technique is essential for the greatest utilization of athletic endeavor. The sport of rowing is a highly skilled activity and even small deficiencies can detract from a rower's performance.

There is more than one way to move a boat fast through the water and gold medals have been won using a variety of different techniques. There is one common factor present in all fast crews, which is that the rowers in those boats apply their power together. As in the old adage, 'a load

shared is a load halved'.

In order to achieve efficiency of effort, the oarsperson must be taught to row with identical movements. This is referred to as 'style'. It is for the benefit of all rowing that rowers be taught a uniform style. It is to the benefit of our international squads if a common style is adopted by all.

Technique has played a minor role in Britain during the past decade. In an environment where success is easier to achieve from physical training than by the slower methods of teaching technique, successes at higher levels have been elusive. Improvements in technique would help to improve the performances of our International crews in the world.

### FACTORS AFFECTING THE PROCESS OF LEARNING A NEW ROWING STYLE

When trying to adapt to a different technique, whether it is a completely new movement or a change, a rower has more difficulty in controlling his actions in certain identifiable circumstances and the learning process slows down.

These problem areas are identified as follows:

1. at high rates of striking
2. at maximum intensity of work



## CREATING TRAINING PROGRAMS

### SPRACKLEN'S NOTES – PART 1

#### TRAINING FOR TECHNIQUE

This training System has been designed to provide a variety of methods that are compatible with the process of learning good rowing technique. The methods are not dissimilar to those used by coaches throughout the

3. in a state of physical tiredness
4. when large increases and sudden changes are demanded
5. when too many changes are to be made at one time

This system avoids the extremes of these adverse conditions. Increases are made in easy stages and only when a rower has shown that he/she is able to cope with the change are further increases demanded of him/her. Training periods of long duration at low rates form the foundation of the System. At low rates the oarsperson is able to control their movements and make corrections as they go when deterioration occurs. The gradual onset of fatigue when training over long distances permits control to be attained. When explosive work is introduced the rower will have built a sound foundation to cope with high demands without loss of form.

The more hours spent on the water practicing a particular movement the sooner that movement will become natural to the rower. This 'grooving in' process is accelerated when the rowers are able to hold good form through long periods of tiredness, but care must be taken to ensure that quality is not lost and that bad faults are not being ingrained. The ultimate test for an rower's technical ability is whether or not he/she can hold good quality when he is under extreme pressure from physical exertion, like the last 250 meters of that one important race!

An outline of the techniques practiced by the men's heavyweight squad are illustrated in this pamphlet. To explain the training methods which will help to achieve good technique is the purpose of this publication.

### **TRAINING**

Whilst importance is placed on the improvement of technique in this System, the training methods have been devised to provide the best preparation for oarsmen at all levels of competition. Training for the improvement of endurance levels is a high priority. Long outings with variations of low rates are essential for the development of strength coordination and aerobic endurance as well as for 'grooving in' new techniques. This System provides guidelines for achieving a sound physical and physiological foundation for 2000-meter racing.

### **TRAINING LOADS**

Training loads have been prepared so that one method can be compared with another even though the work content may be different. The loads have been derived from a mixture of simple mathematics and the experience of crew training up to the highest levels of competition.

- The methods are based on a normal training load representing 80% of a rower's maximum effort. The suffix 'N' after the method code signifies Normal Training Load.
- Maximum loads are suffixed with 'H' signifying High Loads. High loads are equal to 100%

effort and are calculated by increasing a normal load by 25%.

- Reduced loads are suffixed with the letter 'L' signifying low loads and these are generally 25% below the normal load.

The work methods have been prepared on a time basis rather than on distances. This allows a rower to work at his own pace regardless of the type of boat in which he is training e.g. pair, four or single. The intensity of work is programmed to suit the ability of the oarsmen individually or the squad as a whole.

When no suffix is shown against a Method Code, only one set is required. A numeral before the code will indicate the number of sets to be completed.

An example of a training load for an International oarsman who is training twice a day for six days a week would be, five sessions at 'N', normal load, one or two at 'H', high load, 3 or 4 at 'L', low load with one or two light outings.

### **REST PERIODS**

The recovery periods between sets should be sufficient to allow the pulse rate of an oarsperson, after work, to drop below 120 beats per minute. These rest periods are shown as 5 minutes light paddling, but should be reduced as the rower's physical condition improves with training.

### **INTENSITY OF WORK**

All strokes, unless otherwise stated, are rowed as hard as can be maintained for the session. An important part of the system is that pressure is maintained as the rates rise so that an oarsperson is able to apply maximum output to 200 strokes when he needs to!

### **AEROBIC/ANAEROBIC CONTENT**

All work methods below the rate of 30 are continuous for the improvement of aerobic capacity. Where the stretch of water does not permit continuous work, turns should be made quickly and the work set back by 30 seconds. Work above rate 32 contains a high anaerobic content. This type of work is done intermittently with controlled rests between each set piece.

### **WARMING UP AND WINDING DOWN**

Stretching exercises should be made routine, before and after each session. Thirty minutes of warming up paddling should be done before scheduled work commences. A more specific warm up should be adopted before intensive training so that the body is in a fully prepared condition.

Fifteen minutes of paddling after exercise to wind down is important. Gentle muscular contraction helps the body to clear waste products, which have accumulated in the blood stream during heavy exercise

### **RATE CHANGES**

Rates of striking (stroke rate) are changed by only two strokes per minute at any one time. These gradual

changes help the rower to retain technical control during and after the change has been made.

Increases in rates are carried out by generally quickening movements (lively recovery and faster catches etc.) and reductions, by sliding slower forward between strokes.

Rhythm is affected by the speed of the boat. Two or three slightly shorter and quicker strokes will increase boat speed and help the rower to achieve a higher rate whilst maintaining a good rhythm.

It is not easy for a crew to make a rate change and to hold the rate consistently for any length of time. Rates should be checked frequently and adjusted when necessary. It should not be expected that a crew will achieve the rates on every occasion, often the crew will have difficulty in making the change successfully without loss of quality. It is the determination to improve which is of greater value than the actual rate which is scheduled.

### HOW THE SYSTEM OPERATES

A particular point of technique is selected in a rower or crew. This may be emphasis on part of the stroke or a correction to an existing movement. Examples would be:

1. Individual fault corrections
2. Rhythm and slide control.
3. Hands, body, and slide movements in the recover.
4. Greater acceleration of the blade through the stroke and stronger finishes
5. Bladework control.
6. A longer reach forward

A target rate is selected and a period of time for improvement allocated in the training program. At the beginning of a winter period the target rate would be 26 or 28 and the time period about 14 days depending on the difficulty of the change.

The first outing would be a long piece of work at a low rate. The coach would ensure that the correct interpretation and application of the change during this outing, was accomplished.

Various methods involving rate changes below the target rate are introduced to add flexibility and variety to the program. The rowers have to concentrate on control of movements as rates change up and down. Gradually confidence grows and the change is 'grooved in' at the lower rates.

The rates slowly increase throughout the period. Care is taken by the coach to ensure that when deterioration occurs the rate is reduced until good form is reestablished.

At the end of the period the target rate is consolidated with a long row.

If the desired success has not been achieved, the coach decides from which point the schedule should be repeated or whether a new approach should be adopted. If the crew has been successful the coach will select another point of technique for improvement and a similar process is completed. Even at the highest levels there is always room for improvement. No rower is perfect.

The coach uses his/her skills to decide which point of technique are important. He/she will usually work on the weakest link in the chain throughout the training period, gradually improving one fault after another until his crew has achieved good technique at race rate at the end of the winter.

The rate of improvement will of course depend on the ability of the rowers, their motivation, and degree of difficulty of the change and of course the skill of the coach. Perfection is never achieved and the coach decides which points of technique are worth pursuing and those that are not.

### METHODS

The meanings of some words used are as follows:

PROGRAM	The complete training program in its entirety
PERIOD	A specified period of time within the program
SESSION	One complete training session from stretching exercises to winding down.
METHOD	The type of work and its content
SET OR SET PIECE	A piece of continuous work normally part of a Method.
QUALITY CONTINUOUS	Refers to technique Work done without change of pressure.
INTERMITTENT	Work done with light paddling between each set piece

### Note:

"minute" is symbolized by ' ... therefore the following: "change rates at 3' 2' 1' 2' 3' 4' - 11' total" -reads as "change rates at 3 minutes, 2 minutes, 1 minutes, 2 minutes, 3 minutes, 4 minutes - 11 minutes total."

### DESCRIPTION OF "METHODS"

#### PYRAMID

Change rates at 3' 2' 1' 2' 3' 4' - 11' total.  
Rates increase then decrease by 2 at each change.



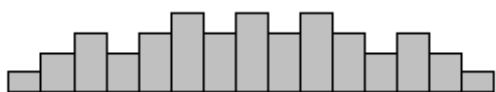
#### CASTLE

Change rates up and down by 2 alternately every 2 minutes.



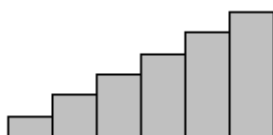
## PYRAMID CASTLE

Change rates by 2 at end of each minute as follows:  
22,24,26,24,26,28,26,26,26,28,26,24,26,24,22. -15'  
total.



## STAIRCASE

Increase rate by 2 at each stage.



## LADDER

Row 20 strokes at each rate with 10 light strokes between each change. Rates increase by 2 strokes per minute. E.g. 24 to 34, 26 to 36 etc



## CONSOLIDATION

Continuous work for the time and rate given.



## SPEED WORK

5 (5 x 20 strokes. 10 light between) rate 36.

Rate 36 - 500 strokes

Rate 36 - 400 strokes

Rate 40 - 300 strokes

viable option for serious weight training, they are best for novice, senior and recreational athletes."

Later, Ms. Quinn noted,

"However, free weights require the help of a spotter, and result in more injuries than machines. Careful instruction and training is necessary to master the art of free weight lifting."

Ms. Quinn isn't the only one stating this. It seems to be conventional wisdom that machines are safer. While the debate "free weights vs. machines" has been around for some time (with very few new ideas brought to the table), I'm still forced to ask if machines really are "safer" than free weights.

Explanations of why machines may be safer than free weights fall under 3 patterns of reasoning: 1. Proper form is needed for the use of free weights, 2. Machines are better in isolating certain muscles, and 3. Many free weight exercises require a spotter. Let's look at these explanations and point out the faults in each argument:

Proper Form Is Needed For The Use Of Free Weights. As noted above, Ms. Quinn states, "Careful instruction and training is necessary to master the art of free weight lifting." While I do believe this to be true, it is also true for the use of machines. Many machines are overwhelmingly misused in health clubs. Lat pull down, seated cable rowing and multi-hip machines being the most commonly abused.

Furthermore, many machines often force the user into improper form by virtue of inherent design flaws. It is very difficult to design a machine that will provide proper biomechanics for all individuals. This is a disadvantage that free weights do not have. Furthermore, the fact that machines are far more complex than a dumbbell results in increased opportunity for accidents.

Consider the case of professional wrestler Sean Morley (aka "The Big Valbowski"). WWE writer, Phil Speer (<http://www.wwe.com>), recently documented a training accident in which Sean Morley was doing seated cable when the machine tipped over on the wrestler, causing him to miss several weeks of work as a result. This may seem like a "freak accident", but chances are if anyone used that particular machine in the same fashion and with the same weight, it will happen again regardless of "proper form".

Machines Are Better In Isolating Certain Muscles. While this is often listed as a positive attribute of free weights, there are some arguments suggesting this makes machines somehow safer to use. The belief is that fewer muscle groups are used and you don't have to balance the weight. This may make the exercise easier - and yes, simple tasks can be safer than complex tasks - but if the overall goal is a stronger, more fit body it is detrimental. If you are using a leg press machine to protect your lower back (even if it is properly designed to do so) the lack of development of the lower back will become your weak link.



# STRENGTH TRAINING

## THE SAFETY OF FREE WEIGHTS

In "[Free Weights vs. Machines: A Look at Pros and Cons of Each](#)", Elizabeth Quinn makes a case for machines being "safer" than free weights. Says she, "The most important component in any strength training program is safety. If you are new to strength training or if you are working out alone, variable resistance machines are the best bet. While machines can be a

Free Weight Exercises Require A Spotter. First, the vast majority of free weight exercises do not require a spotter. Those that do, such as the bench press or squat, do indeed require one. Not having a spotter is potentially dangerous; however it does not make the exercise in itself dangerous. Furthermore, there are equipment companies like SportStrength that manufacture racks and benches with built in spotters. Is there anything else that makes free weight exercises more dangerous than machines? Elaine Zablocki quoted Chester S. Jones, PhD in WebMD Medical News

(<http://my.webmd.com/content/article/1676.53142>)

regarding injury rates amongst weight trainers:

"In a review of data from U.S. emergency rooms, he found injuries from weight-training activities and equipment have increased 35% over a 20-year period. The hand was injured most often, followed by the upper trunk, head, lower trunk, and foot."

Note that this includes both free weights and equipment. The point that should be focused on is that the hand, head and foot are among the leading injuries. Perhaps it is possible to strain or tear a muscle or tendon in your hand and foot, but the majority of these injuries were most likely caused by carelessness. Smashing your fingers while putting away free weights or dropping them on your head or foot can happen. However, don't blame the iron dumbbell! Blame the "dumbbell" who lost their concentration! Besides, far more injuries from carelessness occur on machines than free weights.

So, the decision to use free weights or machines will always exist, and many will still debate the relative benefits and safety of each. However, the belief that machines are safer should be carefully re-examined.

Frederick Hatfield II, M.S.



ASSOCIATION OF ROWING COACHES, SOUTH AFRICA

## RECOVERY

### RESTORATION AND REGENERATION AS ESSENTIAL COMPONENTS WITHIN TRAINING PROGRAMS

Recovery sessions are rarely incorporated into sports specific training programs, except in Eastern Bloc countries. Yet the benefits of structured recovery periods are well documented both in terms of improved performances and decreased injury rates. Coaches and athletes alike need to be more aware of the importance of restoration and regeneration following heavy workloads, and of how to use the modalities available to facilitate recovery.

*Feigley, 1984, Yessis 1986, Crampton and Fox, 1988, Kulpers and Kelzer, 1988. Some of the above*

TABLE 1: SYMPTOMS AND SIGNS OF OVERTRAINING

PHYSIOLOGICAL	PSYCHOLOGICAL
Increased muscle tension	Disturbed sleep
Increased muscle tenderness	Irritability
Decreased VO2 Max	Depression
Increased blood lactates	Increased anxiety
Decreased nerve impulse transmission	Increased fatigue
Decreased aerobic threshold	Decreased vigour
Decreased anaerobic threshold	Depressed mood states
Increased susceptibility to illness	Decline in feelings of self-worth
Decreased appetite	Uncontrollable emotions
Elevated resting HR	Insecurity
Elevated BP	Oversensitive about criticism
Proteinuria	Listlessness
Decreased energy levels	Melancholiness
Increased fatigue = lower tolerance of workloads	

**can be experienced following heavy and intense workloads even though a classic overtrained state has not been reached.**

The desire to provide peak physical and psychological performances during competition necessitates rigorous preparation involving intense and stressful training. Adaptations to heavy workloads are dependent upon the athlete's physical and emotional ability to cope with increased work volumes and intensities. The overload threshold required for optimal improvement without the corresponding problems associated with overtraining is difficult for coaches to gauge. Individual athletes within the same sport can respond differently to the same training loads and preliminary symptoms warning of imminent overtraining are elusive. However, once that state has been reached there are several distinctive physical and psychological markers evident (Table 1).

Unfortunately the effects of overtraining can negate months of hard work and detract from the athletes' full potential. In many situations overtraining leads to 'staleness', then 'burnout' or injury, or both. These require lengthy and often expensive rehabilitatory process for athletes, team and coach. To overcome this problem many Eastern Bloc countries sustain maximal workloads and intensities with minimal detrimental effects by structuring recovery sessions within training regimens (Kopysov et al. 1982; Matusezewski, 1985). The range and scheduling of

recovery modalities is extensive and tailored to suit the requirements of individual athletes and their respective sports (Zalesky, 1982). The systematic inclusion of recovery sessions reduces overtraining problems and injuries and also appears to significantly increase performance by enabling the athlete to cope with greater workloads (Talyshiev, 1980; Birukov and Pogosyan, 1983; Zhang et al, 1987).

### **RECOVERY: RESTORATION, REGENERATION AND REHABILITATION**

Recovery is a generic term used specifically with reference to the restoration of parameters in either or both physiological and psychological states that have been excessively stressed or altered during a particular activity. These states contain variables or markers which can be measured objectively (Yessis, 1982:38).

Restoration refers to returning physiological markers to normal levels whereas regeneration refers to the recovery of psychological traits particularly associated with mood states. Rehabilitation refers to

recovery from injury or illnesses which are often the result of overtraining. Physiological and psychological recovery are both equally important and excessively stressed athletes may exhibit symptoms or signs indicative of overtraining, in both states (Table 1). Some of the signs and symptoms shown in Table 1 can be experienced following heavy and intense workloads even though a classic overtrained state has not been reached.

### **RECOVERY METHODS**

Recovery methods fall into four major categories:

- (1) Work/rest ratios, including light active recovery**
- (2) Nutrition**
- (3) Physical Therapy**
- (4) Psycho-Regulatory Training (PRT)**

Restoration and regenerative programs followed by Eastern Bloc countries employ all of these procedures in varying proportions depending on training workloads,

the demands of the sport, and the individual needs of the athlete (Sports (eds) 1986: Fox, 1986:9). Zalesky, also notes that the type and amount of restoration employed depends on the extent of the athlete's state of fatigue (1984:53).

### **WORK/REST RATIOS**

Work/rest ratios vary both within and between work sessions. Successful schedules for specific sports are well documented from the West as well as the Soviet Bloc. The body requires recuperative time to allow for adaptive processes to occur and promote anabolic activity such as strength gains. Consequently rest periods need to be programmed into training schedules, but these vary depending on the requirements of the sport and intensity of the workload.

For example, prescribed rest days for jumpers and throwers differ despite the fact that both are explosive anaerobic sports (Bakarinov and Zalesky, 1982).

Although most track and field athletes have one passive rest day per week, workloads vary both within daily sessions and between training phases. For example, the training volumes and intensity

between the preparatory phase and the competitive phase differ. A high compensatory effect is achieved in the preparatory period via three consecutive weeks of increasing workloads, followed by a fourth week with significantly lighter training.

During the competitive period the lighter training loads extend over two weeks. Alternating training loads between sessions and incorporating active rest periods is designed to produce an undulating 'wave like' growth curve. Peaks and troughs correspond to workloads (volume and intensity) and rest.

Daily programs for track and field athletes usually begin with lighter morning sessions which have a preparatory role before the heavier main sessions during the middle of the day. Evening workouts are lighter and designed to restore the functional capabilities of the athlete.

Cross training activities can be used as a form of active rest, especially during the competitive phase. This can help switch the psychological direction of the athlete to rest better from the specialized event and help to



restore the functional capabilities of the central nervous system.

## **NUTRITION**

Similarly nutrition and the dietary requirements for sporting events require careful programming. The body requires food not only for energy but also for anabolic and reparative processes. The link between overtraining and a depressed immune state is also an area of recovery being addressed through nutrition (Telford, 1990). A poor or inadequate diet can lead to fatigue, irritability, and sometimes to eating disorders such as anorexia.

Training and competitive diets will vary according to the type of activity being undertaken. Adequate intakes of complex carbohydrates are essential for all athletes, but especially crucial for events lasting over one hour. Carbohydrate loading or 'super-compensation' practices are designed to maximize the storage of glycogen and prevent the early onset of fatigue. Rehydration can also prevent fatigue and assist athletes to sustain the intensity of a training session.

All athletes require a well balanced diet containing the essential macronutrients of meat, fish, dairy products, fruit and vegetables, cereals and bread. Protein is especially important for muscle regeneration and the prevention of exercise-related anemia. In particular, athletes involved in anaerobic activities require additional dietary protein to facilitate training adaptation and recovery.

The interplay between the immune system, white cell production, the production of free radicals and those athletes involved in continual heavy oxidative metabolic activities, is complex. Antioxidants such as vitamins E, A and C provide protection against the action of free radicals, and dietary supplementation of these vitamins may assist athletes in maintaining heavy training loads.

Similarly, minerals are important for muscle regeneration. Muscle cell damage can result from strenuous training or alter the balance of sodium, potassium and magnesium within cells leading to chronic fatigue and tiredness. Extra intake of minerals and trace elements may be necessary to assist recovery, but synthetic supplementation may not be as effective as increased dietary sources, due to the reactivity of some elements and metals with other foodstuffs in the gut.

Special attention is required for food intake pre and post training, and during competition, to maximize energy stores, minimize fatigue and to assist with tissue regeneration.

## **PHYSICAL THERAPY**

The most commonly used modalities relate to a wide range of physical therapies available. Water therapies include a variety of spa, float tanks, baths, (contrasting temperatures, ionizing, and aromatic), hydromassage, whirlpools, Sharko showers and floating stream

showers. Sauna (dry baths) are frequently used with specific regimens developed for different sports and workloads, and decompression chambers (baromassage) are used in the Soviet Union for extremely fatigued muscles. Eastern European countries also use a wide variety of electrotherapeutic procedures for restoration whereas many of these are largely restricted to rehabilitative roles in the West. Ultra high frequency modalities, magnetic field generators, interferential and ultra sound are some of those most frequently employed.

## **MASSAGE**

The most common and frequently used restorative modality for both East and West alike is massage. This is relatively inexpensive and can provide for both restorative and regenerative recovery, plus give the individual athlete specific feedback about the physical state of specific body parts.

There are five basic terms describing different massage maneuvers, vibration (shaking), tapotement (percussion), petrissage (kneading), effleurage (stroking) and friction (small range intensive stroking). (Yessis, 1986; Kresge, 1988.)

Sports massage uses different combinations of these techniques and, relative to training times, is regarded by many authors as the most effective means of recovery. Apart from massage sessions for rehabilitative reasons, treatments are administered during three phases:

(a) Within the training phases where massage is given during the work sessions to help accommodate for high training loads and to increase the athlete's training potential. (Zhang et al. 1987).

(b) Preparatory massage given as part of a warm-up phase, some 15-20 minutes before competition. This can either relax an overstimulated athlete or arouse an apathetic one.

(c) Restorative massage is given in the post-training or post-competitive phase. This procedure is regarded as being at least two or three times more effective for recovery than passive rest. (Birukov and Pogosyan, 1983). These treatments facilitate recovery from the effects of fatigue, the reduction of muscle tension and a lowering of stress levels.

The timing and frequency of restorative treatments is dependent on the type of activity, intensity and individual athlete (Kopysov et al, 1982). When heavy workloads are undertaken most authorities recommend restorative massage 2-6 hours following the completion of training (Yessis, 1982). Frequency of treatments varies from 1-2 per week to three times per day. This variability relates to the sport undertaken, intensity of the recovery program and the availability of a masseur.

The duration of each treatment also varies according to the amount of body surface to be massaged. Whole body or general massage requires more time than a localized treatment concentrating on a specific area or body part. Some authors also adjust treatment times according to the athlete's weight (Matusezewski, 1985). Whole body massage lasts from 40-90 minutes while localized procedures range from 10-30 minutes. The general restorative effects of massage have been summarized by Ylinen and Cash (1988).

Although a few studies have considered the psychological effects of massage, the physiological benefits have been examined in more detail (Wakim 1981). The mechanical effects of massage have often been considered in relation to physiological responses.

The squeezing, stroking, compressive and pushing components of manual manipulation facilitate drainage of venous blood and lymph. Venous and lymph back-flow is inhibited by valves, consequently altered vascular pressure due to massage facilitates blood flow. Lymph vessels are affected in the same way.

Mobilization of tissues occurs as they are moved on one another. Manipulations cause slight stretch thus maintaining elasticity and regaining mobility where tissues have adhered within themselves or to adjacent tissues. This mobilizing effect is enhanced by improved blood supply which causes increased warmth of the body part.

Massage as part of a warm-up regimen facilitates preparation for the sporting event but is not as effective alone as a combined active warm-up with stretching and some massage. Massage is also an effective adjunct for assisting flexibility, but it should not replace

modality. Accupressure and acupuncture are concerned with balancing energy fields via specific points located on 14 meridians which pass through the body. Acupuncture points have a lower cutaneous electrical resistance than adjacent areas and these can be measured and evaluated. Stimulation of specific points are claimed to influence oxygen uptake, respiration, the immune system and biochemical activities including the uptake of glucose, phosphocreatine, cholinesterase, hydroxytryptamine and acetylcholine (Wong 1983).

### PSYCHO-REGULATORY TRAINING (PRT)

Psycho-Regulatory Training refers to a number of processes generally used to aid an athlete's emotional and psychological state following stress. Relaxation techniques, autogenic training, breathing exercises, musical and light influences, psycho-regulatory training, relaxation massage and flotation are the most frequently used modalities.

Although passive rest is an important component of recovery, the time spent during passive rest can be used to incorporate one of several PRT procedures. Meditation trains the athlete to develop the amplitude and regularity of alpha brain waves in order to produce relaxation. In turn this generates an integrated reflex mediated by the CNS which works in opposition to the flight or fight response. Meditation results in a hypometabolic state, with lowered BP, HR and decreased blood flow, indicating a calming of the sympathetic NS. This can be used to counter the stress of training or competition which can cause over arousal of the sympathetic NS (Wallace and Benson 1972).

Progressive muscle relaxation (PMR) and positive cognitive intervention are both components of psycho-regulatory training. PMR is a somatic relaxation treatment which uses both active and passive components of attention. The consequent reduction in muscle tension improves the athlete's reaction profile and when used in the daily training program can lead to significant improvement in training and competitive abilities (Litschka-Schimpf et al. 1988).

Relaxation massages and flotation assists with muscle relaxation and result in lower HR, BP and improved mood states. These modalities are often used once or twice a week each (Yessis 1986). Modalities such as PMR, PRT, meditation and the use of music can be used daily in conjunction with training sessions.

### GENERAL CONSIDERATIONS

The four major recovery areas offer a great deal of scope for designing a recovery regimen specific to the physiological and psychological needs of each athlete. Notwithstanding this fact, these recovery sessions should be regarded as additional to the proper normal training procedures involved within each session. An appropriate warm-up and cool-down regimen should

**Table 2 Effects of Massage**

MECHANICAL	REFLEXORY
Friction warming	Relaxation
Pumping circulation	Pain reduction
Stretching soft tissue	Opening microcirculation
Breaking scar tissue	Balancing autonomous nervous system
Breaking adhesions	
Increased tissue permeability	
Opening microcirculation	
Enzyme release	
Improved tissue elasticity	

stretching schedules programmed for warming up or recovery.

In the Eastern Bloc and Asian nations, accupressure and acupuncture complement massage as a recovery

include locomotor activity and stretching routines suited to the preparatory or recovery section of the session.

All athletes should be encouraged to stretch in a warm environment wherever possible. Spas, saunas and showers are ideal places to stretch and self massage can be used by athletes. A regular sleeping pattern and sound diet are also essential components of a well balanced training program. For an athlete to maintain demanding workloads without either a loss of performance or increasing the risk of injury, a structured recovery program within the training regimen



is essential.

## REFERENCES

- Bahrinov Yu. and Zalessky M. (1982) 'Restoration in thrower, Soviet Sports Review, Vol.17, pp. 162-164. (translated from Legkaya Atletika, Vol 6, pp. 12-13, 1981). /
- Birukov A.A, and Pogosyan M.M. (1983) 'Special means of restoration of work capacity of wrestlers in the periods between competitive bouts, (Condensed), Teorlya I Praktika Fizicheskoi Kultury, Vol. 8, pp 21-24. /
- Bompa, T. (1987) "Periodisation as a key element of training, Sports Coach, April-June, 20-23. /
- Crampton J. and Fox J. (1987) 'Regeneration vs burnout. Prevention is better than cure, Sports Coach, Vol. 10, No. 4, pp. 7-10. /
- Feigley D.A. (1984) 'Psychological burnout in high-level athletes, The Physician and Sportsmedicine, Vol. 12, No. 10, pp. 109-119. /
- Fleck S.J. (1988) 'Signs and symptoms of overtraining in the anaerobic sport of Judo, in Overtraining and Recovery, Australian Coaching Council Conference Papers, Canberra, pp. 2.18-2.31. /
- Fox J. (1986) 'The effect of the intentional usage of various forms of regenerative procedures on mood state in Australian athletes, A graduating paper presented to the F.I.T. Research Committee in fulfillment for
- Graduating, Footscray Institute of Technology, Victoria. /
- Kipysov V.S., Poletayev P.A. and Prilepin A.S. (1982) 'The distribution of training loads and means of restoration in the preparation of weightlifters, Soviet Sports Review, Vol 17, pp. 49-52. (Translated from Tyazhelaya Atletika, Vol. 10, pp. 20-23, 1981). / Kresge C.A. (1988) 'Massage and sport, in sports medicine: fitness, training, injuries', O. Appenzeller (ed.), 3rd edition, Urbane and Schwarzenberg, Baltimore, pp. 419-431.
- Kuipers H. and Keizer H.A. (1988) 'Overtraining in elite athletes, Sports Medicine, Vol. 6, pp. 79-92 /
- Litske-Schimpf G.G., Manz A., Schimpf M., Weib H., Eberspacher and Weicker H. (1988) 'Influence of different experimental recreational treatments on sympathoadrenergic and metabolic regulation mechanisms in repeated exercises', Int. J. Sports.Med. 9:14 6-150. /
- Sports (eds) (1986) 'Regeneration alternatives in high performance sport, Sports Science Periodical on Research and Technology in Sport, Physical Training W-1. (Adapted from Das, "Betreuungs system in Modern Hockleitungssport" from Deutscher Sportbund: Bundesausschuss Leistungssport). /
- Talyshev F. (1980) 'Recovery', Soviet Sports Review, Vol.15, No. 3. (Translated from Legkaya Atletika, Vol 6, pp. 25, 1977.) / Telford R.D. (1990) 'Regeneration - a nutritional perspective', Excel, Vol. 6, No. 2, pp. 25. /
- Wakim K.G. (1981) 'Physiologic effects of massage, in Manipulation, Traction and Massage, J.V. Basmajian (ed), 3rd edition, Williams and Wilkins, Baltimore, pp. 256-269. /
- Wallace R, and Benson H. (1972) 'The physiology of meditation, Scientific American Feb 125 -131. / Wong B. (1983) Meridian Research Abroad, People Health Publishers, China: 374-408. /
- Yessis M. (1982) 'Restoration: or increasing the ability to do more voluminous and higher intensity workouts, Nat. Strength and Conditioning Journal, June-July, pp. 38-41. /
- Yessis M. (1986) 'Recovery Part One, Sports Science Periodical on Research and Technology in Sport, July 1986, General W-1. / Ylinen, Jarl and Cash, Mel (1988) 'Sports massage, Stanley Paul, London. /
- Zalessky M. (1982) 'Restoration for jumpers', Soviet Sports Review. Vol. 17, pp. 1-6. (Translated from Legkaya Atletika, Vol. 11, 20-

23, 1980). / Zalesky M. (1984) 'Restoration in the sprint and hurdles, Soviet Sports Review, Vol. 17, pp. 105-107. (Translated from Legkaya Atietika, Vol. 4, pp. 6-7, 1981). /

- Zhang Z.B., Carter R.M., Minikin B.R. and Telford R.D. (1987) 'The influence of repeated massage on leg strength, paper held at the Australian Institute of Sport, Canberra.



## PHYSIOLOGY

### HEAT ACCLIMATIZATION

Subsequent to repeated bouts of exercise in a hot environment, there is a marked improvement in the physiologic responses of healthy humans. This improved tolerance to exercise in heat is known as heat acclimatization. When accomplished in an artificially controlled environmental chamber, this process is known as heat acclimation. The primary benefit of heat acclimatization is improved tolerance of exercise in the heat, evident as a reduction of the incidence or severity of symptoms of heat illness, and increased work output concurrent with reduced cardiovascular, thermal, and metabolic strain.

#### Physiological Responses

Heat acclimatization is specific to the stress imposed on the human body. For example, passive exposure to heat induces some responses, notably an improved ability to dissipate heat. In contrast, physical training in a cool-dry environment results in metabolic, biochemical, hematologic, and cardiovascular adaptations. Heat acclimatization via strenuous exercise induces responses attributed to both passive heat exposure and training in cool environments. Table 1 illustrates these relationships.

Complete heat acclimatization requires up to 14 days, but the systems of the body adapt to heat exposure at varying rates. The early adaptations (initial 1-5 days) involve an improved control of cardiovascular function, including expanded plasma volume, reduced heart rate, and autonomic nervous system habituation which redirects cardiac output to skin capillary beds and active muscle. Plasma volume expansion resulting from increased plasma proteins and increased sodium chloride retention, ranges from +3 to +27%, and is accompanied by a 15-25% decrease in heart rate. This reduction of cardiovascular strain reduces rating of perceived exertion, which is proportional to central cardiorespiratory stress, also decreases during the first five days of exercise-heat exposure. Plasma volume expansion is a temporary phenomenon, which decays during the 8th to 14th days of heat acclimatization (as do fluid-regulatory hormone responses, see below), and then is replaced by a longer lasting reduction in

skin blood flow that serves to increase central blood volume.

The regulation of body temperature during exercise in the heat is critical, because of the great potential for lethal hyperthermia. Thermoregulatory adaptations (i.e., increased sweat rate, earlier onset of sweat production), coupled with cardiovascular adjustments, result in a decreased central body temperature. This response is maximized after 5 to 8 days of heat acclimatization. However, the adaptations of eccrine sweat glands are different during humid and dry heat exposures. Heat acclimatization performed in a hot-humid condition stimulates a greater sweat rate than heat acclimatization in a hot-dry environment. Also, the absolute rate of sweating influences thermoregulation. If hourly sweat rate is small (<400-600 ml), a peripheral adaptation of whole body sweat rate may not occur.

Conservation of sodium chloride (NaCl) also occurs during heat acclimatization. The NaCl losses in sweat and urine decrease during days 3-9 of heat acclimatization, resulting in an expanded extracellular fluid volume. Subsequently, NaCl losses in sweat and urine increase toward pre-acclimatization levels, once physiologic strain (i.e., cardiovascular, thermal) moderates. Francesconi and colleagues (1993) recently demonstrated that NaCl losses, during a strenuous 10-day heat acclimatization protocol, were related to plasma renin (PR) and plasma aldosterone (A) concentrations. When subjects consumed a low salt diet (4g NaCl per day) and a moderate salt diet (8g NaCl per day), both PR and A increased during the first four days of heat acclimatization, but decreased during the remaining 6 days of heat acclimatization. The improved cardiovascular stability, which occurred on days 1-4 of heat acclimatization, allowed equivalent exercise performance with both diets and apparently reduced the stimulation and need for large elevations of PR and A. No change in plasma levels of arginine vasopressin (AVP) were observed across time, in either dietary group, possibly because hourly water intake matched the fluid lost in sweat. Usually, AVP synthesis is stimulated by an increase in plasma osmolarity or alterations in blood pressure, plasma volume, and renal or hepatic blood flow.

Therefore, it is unlikely that the ability to successfully sustain exercise, during the latter days of the heat acclimatization process, is specifically related to the action of hormones that regulate fluid-electrolyte balance. This is particularly true when salt balance has been achieved.

Excess dietary water and electrolytes do not speed the process of heat acclimatization. When dehydration or salt deficits exist, however, cardiovascular and thermoregulatory responses may be negatively affected, and the theoretical risk of heat illness increases. Consistent daily monitoring of body weight will allow athletes to recognize water deficits which require consumption of fluid (-2 to -3% of body weight), reduction of training duration/intensity (-4 to -6%), or

consultation with an experienced physician (in excess of -7%).

Plasma cortisol concentration generally indicates the strain experienced by the body. Heat-acclimated, well-hydrated humans exhibit no change in plasma cortisol when exercise in a hot environment is mild. Under the same conditions, the lack of heat acclimatization and dehydration can result in large plasma cortisol increases. When exercise is intense and core body temperature rises markedly, the plasma cortisol concentration increases during the initial days of heat acclimatization, but returns to control levels after 8 days of heat acclimatization, reflecting the reduction in total body strain.

Physical training in a cool environment may or may not improve exercise economy. Metabolism can be affected by heat

acclimatization, in that oxygen uptake during submaximal exercise is reduced. Large effects have been reported for stair stepping; treadmill and cycle-ergometer exercise produce smaller, but statistically significant, changes. The physiologic mechanism has not been defined exactly, but three theories exist: (a) blood flow to the skin increases, thus reducing central blood volume, venous return to the heart, and cardiac output; (b) the portion of cardiac output perfusing muscle decreases; and (c) the recruitment of muscle fibers shifts from predominantly oxidative to glycolytic fibers. Heat acclimatization reduces muscle glycogen utilization and post-exercise muscle lactate concentration.

**Heat Illness**

Heat acclimatization is of interest to physicians as well as athletes, because it reduces the incidence of heat illness and the intensity of symptoms. The most common heat illnesses among athletes are heat cramps, heat syncope, and heat exhaustion. Heat cramps are usually unheralded and occur in the voluntary muscles of the legs, arms, and abdomen, after several hours of strenuous exercise in individuals who have lost a large volume of sweat, have drunk a

large volume of hypotonic fluid, and who have excreted a small volume of urine. Sodium depletion probably causes heat cramps. Heat acclimatization decreases the risk of experiencing heat cramps.

Heat syncope (e.g., fainting) occurs most commonly during the first 3-5 days of heat exposure. This illness

is related to the shunting of blood through dilated cutaneous vessels, postural pooling of blood, diminished venous return to the heart, reduction of cardiac output, and cerebral ischemia. Heat syncope typically occurs when the ambient temperature or humidity rises suddenly, or when a non-acclimatized individual performs exercise in a hot environment. Heat acclimatization reduces the incidence of heat syncope to nearly zero, after 3-5 days of exercise-heat exposure.

This period corresponds with cardiovascular

stabilization, early in the course of heat acclimatization (see above). Heat syncope is a syndrome distinct from heat exhaustion, because water and salt depletion do not always contribute to heat syncope. Heat exhaustion is the most commonly diagnosed form of heat illness among athletes, despite the fact that its symptoms are often vague and differ greatly from one situation to another. Clinical descriptions include various combinations of headache, dizziness, fatigue, hyperirritability, tachycardia, hyperventilation, diarrhea, piloerection, hypotension, nausea, vomiting, syncope, heat cramps, as well as "heat sensations" in the head and upper torso. This explains why heat exhaustion is defined as the inability to continue exercise in a hot environment, and involves a diagnosis of exclusion. Heat acclimatization significantly reduces the signs and symptoms of heat exhaustion, after eight days of strenuous, intermittent running. The three aforementioned heat illnesses all involve either fluid-electrolyte balance, extracellular volume and tonicity, or cardiovascular adaptation. This emphasizes the importance of (a) ample dietary intake of NaCl and fluids, and (b) fluid-electrolyte hormone regulation during heat acclimatization.

**Table 1: The effects of 14 days of passive and strenuous exercise protocols in cool and hot conditions on selected physiological responses (Armstrong and Maresh, 1991).**  
 Symbols: O = minimal effect; + = moderate effect; ++ = major effect.

Physiological responses	No exercise hot conditions	Exercise cool conditions	Exercise hot conditions
Lower core temperature at the onset of sweating	++	+	++
Increased heat loss via radiation & convection (skin blood flow)	++	++	++
Increased plasma volume	+	+	++
Decreased heart rate	O	++	++
Decreased core body temperature	++	+	++
Decreased skin temperature	+	+	+
Altered metabolic fuel utilization	O	++	++
Increased sympathetic nervous system outflow (efferent)	+	++	++
Increased oxygen consumption	O	++	++
Improved exercise economy	O	O	+
Adaptation to exercise in a cool environment	O	++	++
Adaptation to exercise in a hot environment	+	+	++

### Factors Affecting Acclimatization

It is believed that host factors may influence the capacity to acclimatize to exercise in a hot environment. For example, older persons were previously thought to be less heat tolerant than their younger counterparts. Middle aged men (>45 yr) were shown to have higher heart rates, higher rectal temperatures, and lower sweat rates than young men, during exercise in the heat, both before and during exercise in the heat, both before and after heat acclimatization. Similarly, studies conducted in the late 1960s suggested that women were less tolerant of exercise in a hot environment than men.

However, recent research has qualified and/or reversed these viewpoints. It is now recognized that few gender-related differences exist, when female and male subjects are matched for pertinent physical and morphological characteristics. It is also recognized that differences between older and younger subjects are not necessarily due to aging per se, but may be due to other factors such as decreased training volume and lower maximal aerobic power (VO<sub>2</sub>max)

Most experts agree that intense physical training in a cool environment improves physiologic responses and speeds the process of heat acclimatization. During training in cool conditions, optimal physiologic adaptations may be achieved if strenuous interval training or continuous exercise, at an intensity above 50% of VO<sub>2</sub>max, is performed for 8-12 weeks. Maintenance of an elevated core body temperature appears to be the most important physiologic stimulus.

Irrespective of physical training, VO<sub>2</sub>max generally influences physiologic responses during the development of heat acclimatization. Individuals with a high VO<sub>2</sub>max (>60 ml.kg<sup>-1</sup>.min<sup>-1</sup>) exhibit superior heart rate and rectal temperature responses, and usually reach a stable heat acclimatization state faster, when compared to those with a low VO<sub>2</sub>max (<40 ml.kg<sup>-1</sup>.min<sup>-1</sup>). However, maximal aerobic power per se may not be as important in conferring heat tolerance as the underlying physiologic adaptations (i.e. altered blood volume, vasodilation/vasoconstriction, and muscle metabolism) which result in VO<sub>2</sub>max differences between individuals. A recent publication by Pandolf et al. (1988) demonstrates this concept well. They exposed nine young men (21 y) and nine middle-aged men (46 y) to a 10-day heat acclimatization protocol (100 min treadmill walking per day, 49°C air temperature). The results of testing on Day 1 indicated that middle-aged men were able to exercise longer, had lower heart rates and rectal temperatures, and exhibited greater whole-body sweat rates than young men. The differences persisted for the first few days of heat acclimatization, but were absent by day 10 of heat acclimatization. Both groups were closely matched for body mass, surface area, percent body fat, and maximal aerobic power (51 versus 53 ml.kg<sup>-1</sup>.min<sup>-1</sup>, respectively). The factor that distinguished these two groups was their level of regular weekly physical training: middle-aged men ran an average of 39 km per

week, whereas young men averaged only 8 km per week.

The phrase "heat intolerance" has been used in a wide variety of contexts. Interestingly, heat intolerance has been defined by some experts as an inability to develop normal physiologic adaptations, during repeated days of exercise in a hot environment. Some humans do not show the classic decreases in heart rate and rectal temperature that exemplify successful heat acclimatization. This has been of particular concern among persons with cardiovascular disease and prior heat stroke patients. One recent publication (Armstrong et al., 1990), however, reported that 9 out of 10 prior heat stroke patients exhibited normal heat acclimatization responses (90 minutes treadmill walking per day, 7 days, 40°C air temperature), 61 days after experiencing heatstroke.

### Loss of Acclimatization

The physiologic adaptations to exercise training in a cool environment are lost after several weeks or months of inactivity. In contrast, heat acclimatization adaptations may vanish after only a few days or weeks of inactivity (i.e., 18-28 days). The first adaptations to decay are those that develop first: heart rate and other cardiovascular variables. The rate of decay of adaptations is affected by the number of heat exposures per week, the number and format of training sessions, and the degree to which core body temperature is elevated. Athletes with high VO<sub>2</sub>max usually will lose heat acclimatization adaptations slower than individuals with low VO<sub>2</sub>max.

### References

- Armstrong, L E, J P De Luca, and R W Hubbard. Time course of recovery and heat acclimation ability of prior exertional heatstroke patients. *Med. Sci. Sports Exerc.* 22: 36-48, 1990.
- Armstrong, L E and C M Maresh. The induction and decay of heat acclimatization in trained athletes. *Sports Med.* 12: 302-312, 1991.
- Armstrong, L E and K B Pandolf. Physical training, cardiorespiratory physical fitness, and exercise - heat tolerance. In: *Human Performance Physiology and Environmental Medicine at Terrestrial Extremes*, K.B. Pandolf, M.N. Sawka, and R.R. Gonzalez (Eds.). Indianapolis: Benchmark Press, 1988, pp. 199-226
- Francesconi, R P, L E Armstrong, N M Leva, R J Moore, P C Szlyk, W T Matthew, W C Curtis, R W Hubbard, and E W Askew. Endocrinological responses to dietary salt restriction during heat acclimation. In: *Nutritional Needs in Hot Environments*, B.M. Marriott (Ed.). Washington, D.C.: National Academy Press, 1993, pp. 259-276.
- Greenleaf, J E and C J Greenleaf. *Human acclimation and acclimatization to heat: A compendium of Research*. Moffett Field, CA: Ames Research Center, Technical

Memorandum no. TM X-62008, 1970, pp. 1-188.

- Hubbard, R W and L E Armstrong. The heat illnesses: biochemical, ultrastructural, and fluid-electrolyte considerations. In: Human Performance Physiology and Environmental Medicine at Terrestrial Extremes, K.B. Pandolf, M.N. Sawka, and R.R. Gonzalez (Eds.). Indianapolis: Benchmark Press, 1988, pp. 305-359.
- Pandolf, K B, B S Cadarette, M N Sawka, A J Young, R P Francesconi, and R R Gonzalez. Thermoregulatory responses of matched middle-aged and young men during dry-heat acclimation. J. Appl. Physiol. 65: 65-71, 1988.
- Sawka, M N, C B Wenger, A J Young, and K B Pandolf. Physiological responses to exercise in the heat. In: Nutritional Needs in Hot Environments, B.M. Marriott (Ed.). Washington, D.C.: National Academy Press, 1993, pp. 55-74.
- Sciaraffa, D, S C Fox, R Stockmann, and J E Greenleaf. Human acclimation and acclimatization to heat: a compendium of research, 1968-1978. Moffett Field, CA: Ames Research Center, National Aeronautics and Space Administration Technical Memorandum no. 81181, 1981, pp. 1-102..
- Wenger, C B Human heat acclimatization. In: Human Performance Physiology and Environmental Medicine at Terrestrial Extremes, K.B. Pandolf, M.N. Sawka, and R.R. Gonzalez (Eds.). Indianapolis Benchmark Press, 1988, pp. 153-198.



# Components of a Training System

