Block Periodization: Breakthrough in Sport Training

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Section 2 –**Designing the training programs.**

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Preface.

This book deals with how to improve training routine and how to prepare athletes more successfully for top-performance. The bases of contemporary training were founded a few decades ago when the knowledge was far from completeness and level of workloads, results and demands were much lower than now. At that time the traditional *training periodization*, meaning a division of the whole seasonal program into smaller periods and training units, was proposed and elucidated. This traditional periodization was republished many times and became a universal and monopolistic approach to training planning and analysis. However the further sport progress emphasized contradictions between traditional periodization and successful experiences of prominent coaches and athletes. Gradually these experiences led to alternative coaching concepts and, ultimately, a revamped training approach coined as *Block Periodization.* Its general idea presupposes the use and sequencing of specialized mesocycle-blocks, where highly concentrated training workloads are focused on a minimal number of motor and technical abilities. Unlike the traditional periodization where simultaneous developing of many abilities is prevalent, the block concept proposes consecutive training stimulation of carefully selected fitness components. The new approach has been implemented in various sports and has led to outstanding athletic achievements. Therefore, the purpose of this book is to introduce *Block Periodization* of sport training as the general concept and the basis for a revamped approach to training construction and elucidation.

This book is intended for coaches who perceive their daily pursuit as a creative profession. Coaching as a profession requires a very special combination of knowledge and experience. The author's challenge is to show how the knowledge implemented in practice can form a new positive experience, and how by summarizing experience - new knowledge can be generated.

This book is written for athletes who want to understand why their results do not always meet their expectations. Success in modern sport requires a huge efforts and total dedication. However the willingness to work harder and harder depends on the athlete's consciousness with regards of aims, means and methods of training. The challenge that this has set for itself is to give the athletes a comprehensive explanation of why they must to train hard and how to do it wisely.

This book is for the researchers and other curious people, who are looking for new (or relatively new) concepts, approaches and training designs. In fact, the sport training deals with the continuous investigation of human nature and coaches, at least the more creative among them, are the true researchers. It is likely that this book will stimulate the curiosity and creativity of such readers.

This book is for the students who still retain doubts about the accessibility of scientific backgrounds for the training practice. Perhaps after the reading of this book they will decide that this doubt was superfluous.

The book contains three separate parts, which are united by general idea of Block Periodization that provides both scientific backgrounds and practical consequences of the revamped training system. The first part consists of three chapters which introduce the training backgrounds and basic concepts related preparing athletes; it is intended to provide the readers with the fundamentals of training theory that is necessary for further explanation. Chapter 1 presents basic terms, methods and principles of sport training, which clarify the comprehensive mechanism of the physical fitness improvement and the particularities of the training designing. Chapter 2 elucidates the essence and characteristics of acute, immediate, cumulative, delayed and residual training effects. Chapter 3 contains brief review of the trainability in view of contemporary studies in sport genetics, long-term preparation of athletes, and gender differences in athletic performances and training responses.

The second part is devoted to designing the training programs and contains four chapters. Chapter 4 has a key-function in elucidating the Block Periodization concept. This chapter presents criticism of traditional periodization and provides the bases and benefits of the alternative approach. The next chapters describe general positions and guidelines for training program compilation. Chapter 5 deals with the single workout; namely: workouts' types and structure, sequencing and compatibility of different exercises, compilation of one day training series are described. Chapter 6 explains how to design training microcycles of different types. The mesocycles for accumulation, transmutation or realization are analyzed and discussed. Chapter 7 is devoted to long-term preparation, namely, to annual and quadrennial plans, and bases of long-term preparation of adult and junior athletes. The basic approach to gifted youngsters identification is given special consideration.

The third part pertains two chapters dedicated to performance enhancement. Chapter 8 summarizes original data on the modeling approach to training designing and athletes state evaluation The three-level model is proposed to characterize the entire preparation process i.e. the model of top-performance, the model of sport-specific abilities, and the model of training programs. There are two principal options in modeling approach: to compile collective models for athletes' groups, and/or to elaborate individual models for several athletes. Chapter 9 describes the bases of altitude training; it is focused in particular on how to construct optimal Block Periodization plan that includes training camps at altitude. The proposed guidelines are based on long-term experience of high-level athletes in altitude training.

In summary, during the last decades the achievements of athletes and their sport mastery have improved tremendously. The main factor for this breakthrough, which is obvious to all professional observers, is progress in the preparation of athletes. This progress has been evidenced in many professional reports, anecdotal statements and several publications, mostly journals and coaching magazines. However, current training textbooks and coaching guidelines are still far from complete and a large body of training knowledge is available only to a small group of experts. This book is unique in the field of linking successful experience from sport practice and scientific bases of sport training that should consolidate both empirically proved positions with up-to-date knowledge. The author hopes that the book will meet the expectations of readers who perceive sport training as an area of creativity, self-confirmation and human progress.

Acknowledgements
(to be written)

Chapter 1. Basic terms and principles of sport training

Most of the common basic terms and general concepts of sport training used today were introduced in early 1960s, when sport became an indispensable part of social, cultural and political life. Of course, as in all areas of human endeavor, some common terms remain in dispute and their meaning is ambiguous. This chapter is intended to present and consider the basic terms and concepts in order:

a) to prevent possible misunderstandings; and
b) to introduce the basic terms and concepts necessary for further clarification and explanations.

1.2. Essence of sport training and athletic preparation.

Sport training in its narrower sense means the application of physical loads through physical exercise intended to assure successful participation in competition. Training and competing are closely interrelated. On the one side is training with its focus on competitive content, and on the other are the competitions themselves, which are also part of overall preparation; they serve to prepare athletes for what are called the main or target competition. High-performance athletes usually have one-two target competitions a year and 8-12 other competitions incorporated in their annual program. In addition to competitions and training, the recovery process is extremely important. The recovery process in its broad meaning includes specially planned restorative workouts and exercises as well as other means such as massage, physiotherapy, aquatic procedures, medical treatment, correct nutrition, mental relaxation and the use of natural climatic factors. The trinity of components - training, competing and recovery - forms the content of *athletic preparation*.

It is extremely important to note that athletic preparation contains a number of essential specifically oriented parts that must meet the challenge of solving fundamental problems related to physical abilities, technique, tactics, psychological state, and sport-specific knowledge and thinking (Table 1.1.).

Consider the essential parts of athletic preparation. Physical preparation is its most extensive and comprehensive element. It consists of physical exercises and is intended to improve physical (motor) abilities: strength, endurance, speed, flexibility, and agility. These motor abilities are based on corresponding physiological prerequisites, which are also subject to improvement. Generally speaking, this type of preparation is devoted to improving athletes' physical condition, which is why it is sometimes called *conditioning training.*

Technical preparation includes physical exercises and other drills (demonstration, explanation, analysis, verbal and visual corrections etc.) intended to teach and improve certain technical skills. Ultimately, this process is supposed to help athletes attain their highest degree of technical ability, what is called *technical mastery.*

Tactical preparation relates to measures (specially organized physical exercises, trials, mental drills, modeling etc.) whose aim is to instill cognitive competitive tactics. This enables athletes to make the most effective utilization of their motor and technical abilities in competitions. Very often the term strategy is used as a synonym for tactics. Strictly speaking, strategy refers to the long term planning and regulation of the larger physical, technical, tactical and material resources.

Table 1.1.
The essential parts of athletic preparation.

Parts of athletic preparation	Mission
Physical preparation	To improve physical (motor) abilities and increase the physiological potential of athletes.
Technical preparation	To acquire cognitive technical skills and attain the desired level of technical mastery.
Tactical preparation	To acquire cognitive sport-specific tactics, which allow the most effective utilization of athletes' motor and technical abilities in competitions.
Psychological (mental) preparation	To develop the athlete's personality so that it is harmonious, highly motivated and morally stable. To instill the skills of cognitive self-regulation of the athletes' emotional state in order to facilitate maximal realization of their psycho-physiological potential
Intellectual preparation	To improve athletes' general and sport-specific knowledge in order to effectively complete their training and competitions program

Psychological preparation contains various measures intended to work in two major directions: 1) formation of the athlete's personality so that it is harmonious, highly motivated and morally stable; 2) acquisition and perfection of the cognitive skills to provide the athletes with effective tools for self-regulation of their emotional and psycho-physiological state. Ultimately psychological preparation is intended to facilitate maximal realization of the athlete’s capabilities in sport-specific activities and ultimately in peak performance.

Intellectual preparation covers everything that pertains to comprehension of the sport itself and professionally valuable details related to training, competitions, judgment, equipment, sport media etc. Sport-specific knowledge is of primary importance. This would include:

- the basics of the selected sport: disciplines, technical and tactical backgrounds, training aims and conditions, standards of behavior – partnership, the main ethical norms;
- the basics of competition: rules, program, equipment, athletes' rights and obligations, standards of “fair play “;
- the basics of training methodology: training objectives, means and methods, information about loads and recovery, knowledge of the human body and self-control.

This knowledge is transmitted through conversations, lectures, seminars, the professional literature etc. In particular, the training routine accompanied by brief instructions and explanations contributes to athletes' intellectual education. There is no direct correlation between level of intellectual preparation and sport achievements, however, it is obvious that the world-class athletes are much more informed and educated in terms of their own sport-specific knowledge than medium-class athletes.

It follows from above that physical exercises are used to solve the problems of physical, technical, tactical and, in part, psychological preparation. Particularly valuable are exercises that combine work on motor ability and technical skill, technical skill and tactics, and tactics and psychological stability in the face of emotional stress. Such drills, called *conjugated effect exercises,* are used extensively in sport training.

The diagram in Figure 1.1 displays the content and unity of the components and essential parts of athletic preparation. In the upper part of the diagram, training and competitions determine the essence of athletic preparation and form its content. In the lower part, the main content (training and competitive activities) is realized through the essential parts of athletic preparation: physical preparation, technical preparation etc.

Insert Figure 1.1. about here

One more remark is in order concerning the relation between "training" and "preparation". Very often "training" is used to mean "preparation". This use emphasizes the importance of training as the leading component of athletic preparation.

1.1.1. Objectives, aims and training targets.

Sport training is a goal-oriented process in which athletes follow their aspirations and ambitions as they strive to obtain their objectives and aims. Nevertheless, competitive sport has one specific general objective - *attaining excellence in a selected sport*. This is the specific point of high-performance training, unlike other sport activities like general fitness training, school physical education or the professionally oriented physical training of military forces, sailors, policemen etc. The general objective can be defined more specifically in terms of a specific season or number of years. In sports where speeds, distances, power and other criteria are recorded, this can be expressed as a specific result towards which athletes work; in other sports this can be the position attained in world rankings, etc..

The goals hierarchy can be represented as a pyramid, where the vertex expresses the general objective of excellence (Figure 1.2).

Insert Figure 1.2. about here

Obviously, general goals determine athletes' long-term motivation, life style, habits and behavior. The middle level of the pyramid offers the training aims, namely: developing motor abilities, technical mastery, tactics and strategy, health, sport-specific knowledge. Of course, each sport demands its own profile in terms of these aims, which should be adapted to sport-specific conditions. It is commonly accepted that the content and particularities of tactical abilities in ball games differ greatly from those of endurance or power sports.

The base of the goal-pyramid is formed by training targets, which correspond to concrete tasks of individual workouts or exercises. For instance, the targeted ability of the bench press with sub-maximal load is maximal strength of the upper body. In other words, training targets are the simplest and clearest goals affecting the content and load magnitude of specific workouts. Training targets relate to several motor abilities (strength, endurance, quickness, agility), technical skills or elements, tactical ability, and/or cognitive matters. Usually not more than two-three training targets are selected for a single workout.

Goal setting is of great importance for high-performance preparation and requires special attention and competence from the coach. As has already been noted, the best approach is to characterize the general goals as precisely as possible. This means that the coach has to analyze an athlete's present abilities and make a realistic prognosis for the future. This prognosis can be altered based on two factors: (a) the achieved results and (b) the rate of improvement. It is very important that the general goals be ambitious, well founded, and recognized by the athlete as extremely important and achievable.

All of the above is relevant for the training aims. It is highly desirable to translate the aims into quantitative data in terms of motor, technical and tactical tasks and, if possible, anthropometrical characteristics as well. This quantitative approach to the aims leads to the creation of a "personal model" of the athlete's optimal condition (see Chapter 8).

Setting training targets is an obligatory part of each workout plan. Usually the setting of training targets rarely creates obstacles; the difficulties may begin with the compilation of an appropriate program.

1.1.2. Basic terms of athletic training

The basic terms of training methodology have historically been formed in response to practical demands: there are training goals, training content, training means and training methods. Table 1.2 considers these terms by first asking what these terms question and then answer.

The list of terms begins with "training goals", which have already been reviewed. The next basic term is "training content". All of the activities usually carried out in training have to be systematized according to long-term, medium-term, and short-term plans. These plans prescribe all substantial aspects and details of the coming training and, in fact, thoroughly characterize training content, meaning: participation in competitions and trials, dominant training modalities in different time periods, volume, intensity and repertory of exercises, training camps, testing and exams.

"Training means" refers to all drills involved in the program. They are subdivided into competitive exercises and general fitness exercises. Competitive exercises have a close affinity and similarity to the main technical skills and meaningful components of the competitive program; they are performed under competitive conditions (standard equipment, adherence to competitive rules etc.). Sport-specific (special) exercises include any drills where competitive conditions are modified in order to accentuate several requirements and details, like increased or reduced resistance, technique simplification or transformation, internal or external stimulation, involvement of additional devices or tools, etc. General fitness exercises form a broad part of the training repertory and help enhance general physical development. Usually these exercises are not similar to competitive technique; they exploit different devices and equipment, and a wide spectrum of natural and artificial conditions. Typical examples of such drills are running or swimming exercises for combat and ball games athletes, strength exercises on various training machines for all athletes, ball games for rowers and swimmers etc.

Table 1.2.
Basic terms of athletic training with a brief explanation

Terms	**The questions to be answered**	**Brief answers**
Training goals	What should be achieved and/or trained?	General goals Training aims Training (exercises) targets
Training content	What should be carried out?	Long-term training plan Medium term training plan Short-term training plan
Training means	Which exercises, devices and auxiliary tools should be involved?	Exercises: competitive, sport-specific (special), and general fitness exercises. Technical training means: training machines, devices and diversified equipment
Training methods	How should the exercises be performed?	Continuous uniform exercise Continuous non-uniform exercise Intermittent exercises with given rest intervals Intermittent exercises, unrestricted rest intervals Exercises in game form

An additional group of training means contains different training machines and devices; more or less specialized equipment utilized for any kind of exercises. This group is called “technical training means”. In recent years this group has been augmented by a variety of electronic measurement systems and devices, like computerized training machines, optoelectronic, video- and other systems, etc.

“Training methods” relates to the question of how the exercises should be performed. The answer to this question and its various aspects is the subject of the following paragraphs.

1.1.3. Training methods

Training methods are of primary importance for both training theory and coaching practice. Despite the enormous variety of possible exercise combinations, the available training methods can be classified and subdivided into five major groups (Table 1.3).

Table 1.3.
Methodical principles and characteristics of training methods.

Methodical principle	**Work-rest conditions**	**Name of the training method**
Continuous exercise	Uniform performance	Continuous uniform method
	Non-uniform performance (includes periodical accelerations)	Continuous alternating method Fartlek
Intermittent exercise	Work–rest ratio is strictly prescribed, rest interval is predetermined	Interval method (long-interval, medium interval, and short-interval methods)
	Work duration is predetermined, rest interval is not strictly prescribed and allows complete (or almost complete) recovery	Repetition method
Game exercise	According to game scenario	Game method

Continuous exercises can be performed uniformly (according to velocity or power or movement rate) or not uniformly, by varying these exercise parameters. Consequently, the training methods are indicated as the continuous uniform or the continuous alternating method. The most popular mode of the continuous alternating method is *fartlek*, a Swedish term that can be translated as "speed play". The method as originally proposed for training runners had the group periodically perform several spurts of speed to change the lead runner. Usually this exercise was performed on uneven surfaces and the running spurts were combined with ascents or descents in the terrain. When this method was first employed, exercise content was not strictly prescribed. Somewhat later, the alternating acceleration and low intensity phases became precisely programmed. This is not the truly original "fartlek" but the term has remained for describing a wide spectrum of non-uniform exercises.

Intermittent exercises have more complex characteristics than continuous exercises. Work intervals, number of repetitions, nature of rest (sitting, lying, jogging, floating, active relaxation etc.) are usually strictly programmed. The differentiation between two principal intermittent methods was based on recovery completion. The repetition method describes exercises with rest intervals long enough for complete (or almost complete) recovery and this regime allows athletes to perform exercise requiring higher effort. Consequently, it is suitable for several kinds of trials and competitive simulations. Intermittent performance with strictly prescribed rest intervals is known as the interval method, which is subdivided into three modes (Table 1.4).

The short-interval method is usually utilized for workloads ranging from maximal to high intensity; rest duration differs depending on various factors and lasts from 15 s. to 3 min. The medium-interval method refers to work intervals ranging from 1.5-6 min at relatively reduced intensity and rest intervals of about 1-4 minutes. The long-interval method refers to work intervals ranging from 6-20 min. with intensity reduced to medium level and rest duration of about 2-6 minutes.

Consequently, the net time of all workloads performed using these methods in a single workout varies from 3 min (a sprinter's workout) to 2.5 hours (a marathon runner's workout).

Table 1.4.
Interval method modifications (adapted from Harre, 1982)

Method name	Single load duration	Intensity level
Short-interval method	Less than 1.5 min	Maximal - high
Medium-interval method	1.5 – 6 min	High - intermediate
Long-interval method	6 – 20 min	Intermediate - medium

The game method employs traditional methods where the main loading factor is the game scenario, which may vary greatly from the classic rules of certain games. Mini games and exercises utilizing game activities are very popular in almost all sports for both for junior and senior athletes. Of course, the load level of such workouts can vary widely is and has much less predetermined elements. Nevertheless, the load level can be effectively regulated by using specific motor task conditions and the game itself.

1.2. Training and principles of adaptation

Purposeful training causes multifaceted transformations in athletes' bodies and in this way increases their work capability. From the biological viewpoint, training is a continuous process of athletes' adaptation to various loads. Consequently, training exercises, workouts and different tasks serve as the stimuli for adaptation. In biology adaptation is considered the adjustment process an organism undergoes to changing life conditions. Generally speaking, the adaptation initially described by great physiologist Selye (1950) is one of the fundamental laws of the life sciences. Application of the adaptation principles to sport training was done by Prof. Vladimir Zatsiorsky (1995); athletes' adjustment to increasing workloads is conditioned by three general factors: stimulus magnitude, specificity and accommodation (Figure 1.3).

Insert Figure 1.3 about here

In terms of the law of adaptation effective training should provide an optimal combination of these three general factors and this determines progress in the athletes' work potential. To sum up, the factors mentioned above are the training related principles of adaptation.

1.2.1. Training load magnitude and the overload principle

Training workload causes athletes' responses and serves as the stimulus for their adaptation. Stimulus magnitude can be regulated by three factors: load volume, load intensity, and novelty of exercises. It is important to note that improvements in fitness can be attained only under when the stimulus magnitude is sufficient. The

overload principle postulates *that fitness gain requires a load (stimulus) magnitude that exceeds the accustomed level*.

The consequence of the overload principle is that load magnitude is of primary importance and should be thoroughly evaluated and programmed. The general approach to load magnitude characterization is presented below (Table 1.5).

Table 1.5.
Characterization of the load magnitude

Load component	**General characteristics**	**Possible indicators**
Training load volume	Sum of all performed exercises represented by quantitative characteristic	Total number of workouts for a period for instance, per week, month, year etc. Total training time expenditure during a given period Total exercise mileage during a period Total number of lifts, throws, jumps etc. during a period
Training load intensity	1) A characteristic of how strenuous a given workload is; 2) Sum of exercises performed with increased effort	Effort level (in %) relative to maximum Effort level indicated by heart rate response Correspondence to certain Intensity Zone Partial volume of exercises with increased effort (mileage, time expenditure, number of attempts etc.)
Exercise novelty	Exercise that contains unknown elements/ details or a new combination of known elements	Number of new (or relatively new) exercises integrated in a training program

Training load volume. Historically the simplest way to increase load magnitude was to enlarge training volume. For elite athletes in many sports, the number of workouts started at two-three per week in the 1930s, increased to 6-8 in the 1960s, and reached 9-14 in the 1980s. Workout frequency has remained at the same level since then. For a long time, the desire to increase training volume was considered to be limited by both physiological and social factors. Physiologically it was thought that the upper limits of human reserves had been reached; socially, concerns were voiced about athletes' needs in terms of education, profession, privacy, etc. Despite this, training volume tended to increase in world sports until the end of the 1980s. It is only in the last two decades or so that total training volume has been stabilized and even reduced (see 4.2.). In any case, increasing training load volume is a highly visible measure of personal progress for athletes in any sport. The evaluation of load volume is a routine operation in endurance sports where exercise mileage is traditionally calculated, however this can be a difficult task in ball games or combat sports, where the quantity of sport specific actions is not easy to summarize.

Training load intensity. Training load intensity is actually considered from two aspects:

- as a measure of the effort level in relation to the maximum (sometimes in relation to the level of competition effort);
- as a part of the total training volume, which is performed with increased (higher than usual) effort.

Of course, more intensive exercises evoke more pronounced responses in the athletes' body. Consequently, load intensity is evaluated both by measures of external work (velocity, power, lifted weight), and by means of body response indicators. Heart rate (HR), for instance, is one of the widespread indicators of physiological response. For a wide spectrum of exercises, HR response provides sufficient indication of intensity level.

In recent years, Intensity Zones (IZ) have become widely used in many sports both for planning and for post-exercise evaluation (Viru, 1995). In this approach the whole intensity range is subdivided into a number of IZ (usually five). Each IZ is described by a number of relevant indicators each of which provides a range of values considered appropriate for this zone. Usually blood lactate, heart rate, velocity (or performance time, or power), and movement rate are employed in characterizing a specific intensity zone. Substantial progress in this approach has been achieved in the last decade with the development of new sport technologies like heart rate monitors, portable blood lactate analyzers, and chrono-electronic measurement systems.

Exercise novelty. Novelty of exercise is the third component of training load magnitude and athletes' responses are strongly dependent on how accustomed they are to certain exercises. Nevertheless, unlike volume and intensity, exercise novelty is seldom considered to be an influence on workload factor. It is known that creative coaches search far and wide for original new drills to enrich the training repertory and to make working out more attractive. The effect of these innovations is obtained in a more pronounced physiological response.

Example. Igor Koshkin (USSR), one of the world's most famous swimming experts, who coached three-time Olympic champion Vladimir Salnikov, told other coaches: "If you will start to use standing on the head as an exercise for your swimmers, the initial effect will be remarkable and positive due to its novelty. But its effect will be very short term because this drill doesn't touch on your athletes' swimming-specific abilities".

This remark emphasizes the complexity of the exercise novelty problem. Indeed, it is not difficult to find a drill that athletes are not familiar with, but it is not easy to find an unfamiliar exercise that corresponds to sport-specific physiological, biomechanical and psychological demands. That is why training specificity, which will be considered below, is also an indispensable adaptation factor in sport training.

1.2.2. Training load specificity

As can be seen in Figure 1.3, training load specificity is characterized by the transfer of training results from one task (auxiliary exercise) to another task (main exercise). Normally coaches employ a wide repertory of exercises, most of which can be divided into two groups:

- exercises to improve motor abilities (strength, endurance etc.);
- exercises to improve technical skills.

Of course, these exercises can be combined in order to improve the interaction between motor abilities and technical skills. In any case, the usefulness of each exercise depends on how it affects the main (competitive) exercises. In other words, motor ability transfer and the transfer of technical skills from drills to competitive exercise determine how useful these auxiliary drills are.

Two important features of training result transfer are of particular interest:

- the transfer of technical skills is much more restricted than the transfer of motor abilities;
- both are very dependent on athletes' qualifications. Low- and medium-level athletes are more sensitive for any kind of exercise, including non-specific ones, while training result transfer among high-performance athletes is strongly restricted by the specificity of auxiliary exercises.

Let us consider the transfer of motor abilities and technical skills separately.

Transfer of motor abilities. This transfer mode forms the basis for the use of any general and specific fitness exercises in any sport. Motor ability transfer is much higher in lower level athletes, who are much more sensitive to any kind of physical exercise. The higher the athletes' level, the lower is their sensitivity to non-specific exercises. Moreover, some exercises can have a negative effect on athletes' sport-specific preparedness. This is what makes the assessment of probable transfer of motor abilities so important.

Training result transfer can be assessed by comparing the gains achieved in main and auxiliary exercises. The precise quantitative method of this comparison is described by Zatsiorsky (1995). Table 1.5 presents the qualitative approach to identifying different types of training result transfer based on the relationship between the main and auxiliary exercises.

Table 1.5
Several types of training result transfer with reference to motor ability transfer

Type of training result transfer	Relationship between the main and auxiliary exercises	Example from sport practice
High positive transfer	Gain in the auxiliary exercise causes a proportional (or near proportional) gain in the main exercise	Gain in two-leg long jump causes proportional gain in take-off force in the swimming racing start
Low or medium positive transfer	Gain in the auxiliary exercise causes a relatively small or medium gain in the main exercise	Gain of maximal strength in bench-press has a notable effect on the gain in discus throwing results
No transfer	Gain in the auxiliary exercise does not affect in main exercise results	Gain of maximal strength in bench-press does not affect trunk strength endurance
Negative transfer	Gain in the auxiliary exercise causes decrease in main exercise results	Gain of maximal strength in bench-press causes a decrease in maximal velocity in swimming

It is worth noting that the exercise repertory of high-performance athletes contains not only drills with positive transfer of training effect but also exercises without any immediate influence on performance. The various exercises performed for warming up, cooling down, and active recovery form necessary and useful parts of the training program despite the absence of immediate positive transfer. Several exercises with negative transfer of training results can be used if special precautions are taken to prevent their harmful effect. For instance, maximum strength exercises negatively affect the flexibility of corresponding joints as a result of which range of motion and the entire performance can be impaired. This side effect of maximum strength exercises can be taken into account when designing the training program and appropriate stretching and flexibility exercises can be included to counter the negative effects. An example of positive motor ability transfer can be taken from the practice of top-level Danish soccer players.

Case study. Three groups of soccer players performed various types of strength training three times a week during three off-season months. The first group performed quadriceps exercises at high resistance and low speed (HR-group); the second group performed the same exercises at low resistance and higher speed (LR-group); the third group performed soccer-specific kicking exercises with additional resistance on a pulley machine (Kick-group). The basic strength of quadriceps muscles was evaluated in high resistance movement; the specific strength was evaluated by measuring ball velocity after a kick. The training program resulted in a remarkable increase of basic strength and a negligible gain in kick performance in the HR-group, a slight increase of basic strength and a modest gain in kick velocity in the LR-group, and no basic strength gain and the largest improvement in kick performance in the Kick-group (Figure 1.4). Thus, the high resistance strength training improved players' basic strength but didn't provide positive transfer of this ability to soccer-specific strength, whereas low resistance and high speed strength exercises enabled this transfer to certain extent. Finally, specific kicking exercises didn't affect basic strength but thanks to high positive transfer caused great improvement in kicking performance (Bangsbo, 1994)..

Insert Figure 1.4 about here

Transfer of technical skills. The principal factor limiting technical skill transfer is the neuro-muscular specificity of each sport-specific technique. To maximize positive transfer of skill, the exercise should be thoroughly matched to sport-specific coordination demands. This is why a relatively narrow circle of exercises provides positive transfer (i.e. positive effects) for movement technique improvement. Table 1.6 presents generalized situations in which positive and negative skill transfer is obtained.

Table 1.6.
Several types of technical skill transfer with regard to practice of exercising.

Type of technical skill transfer	Typical approaches and/or exercises	Example from sport practice
High positive transfer	Accentuation of certain technical element or detail within the whole coordinative pattern	Maximal stride rate facilitation during downhill running Accentuation of “elbow up” arm position when working on swim stroke
Low or medium positive transfer	Simulation of sport-specific movements and technical elements on specially designed training machines and/or devices	Simulation of the javelin throw on an indoor inertia device Simulation of figure skating jumps in a gym with additional support and assistance
No transfer	Any exercises not similar to the main exercise in terms of neuro-muscular coordination	Bench press and bench pull exercises performed by runners, rowers, swimmers etc.
Negative transfer	Drills similar in several kinematic characteristics but very different in neuro-muscular coordination	Throwing excessively weighted javelin or discus Paddling in a canoe with excessive additional boat resistance

The general rule of positive transfer is to employ exercises highly similar to the main exercise in terms of neuro-muscular coordination. Usually these exercises can be designed by specifically modifying or accentuating some technical detail, element or/and sport specific demand. One of the suitable approaches to make such modifications is artificially lightening or weighting the main exercise. This is particularly popular to create what are called *velocity assisted* and *velocity resisted* exercises that facilitate higher movement velocity or, contrarily, require the application of greater efforts within the usual motor task (see Maglischo, 1992).

The designing of original training devices and specially modified exercises is traditionally assigned to coaches and sport scientists. Very often these innovations are intended to stimulate specific motor abilities within a sport specific coordinative structure. Usually the problem is to get the desirable effect without diminishing the movement technique. For instance, weighting the javelin allows athletes to obtain higher force but can destroy movement technique if javelin weight is excessive. On the other hand, positive skill transfer is achieved by any kind of movement facilitators that artificially simplifies but does not distort technique. The rowing training machine “Concept”, for instance, allows athletes to develop sport specific muscle endurance when the motor task is substantially simplified (no interaction with water, standard work conditions) but remains coordinatively satisfactory.

Athletes’ preparation contains a wide spectrum of exercises that improve muscle capability and do not affect technical skill. This refers to all fitness exercises performed on non-sport specific training machines. Because they have no neuro-muscular similarity to the main competitive exercise, these exercises have no skill transfer and, therefore, are neutral in terms of movement technique. Another type of exercise may be similar to competitive exercises except for serious discrepancies that have been inserted in the neuro-coordinative movement pattern. Negative skill transfer is a very probable outcome of such drills. For instance, extensive paddling in a canoe or kayak with excessive additional boat resistance can stimulate specific strength endurance but impinges dramatically on movement technique.

1.2.3 Accommodation

Two closely connected features characterize accommodation, an indispensable component of training induced adaptation:

- an increase of work potential, and
- a decrease of reaction to the constant physical load.

The increase in work potential can be characterized by sport-specific indicators like the results of all-out performance, velocity of anaerobic threshold in endurance sports, etc. The constant physical load can be obtained by examining athletes on an ergometer or by testing them at a predetermined velocity or power. Both trends can be shown in the example of a one-season follow-up of world-class kayakers.

Case study. The group of nine qualified kayakers was followed up during one season preparation. There was performed an incremental test on the water (4 times 1000-m) to determine the anaerobic threshold velocity. In addition they performed a standard 1000-m paddling test at a predetermined speed corresponding to medium intensity (the speed was programmed by the lead motorboat). Blood samples were taken after the test. The graphs display a considerable increase of anaerobic threshold velocity in all athletes and a similar decrease in blood lactate accumulation caused by paddling at a constant velocity (Figure 1.5).

Insert Figure 1.5 about here

This example demonstrates that the accommodation process can be monitored by means of tests for athletes at both maximal and standard efforts. This approach can also be utilized in non-measurable sports, like ball games, where the standard load can be programmed by a specific combination of sport-specific elements at a fixed frequency and range of motion.

The accommodation process has many subjective indicators: with increased work potential athletes report greater “freedom of movement”, improved breathing during extensive work, better muscles relaxation, enhancement of sport-specific feelings like “sense of water” in aquatic sport, “sense of ice” in skating, etc.
All these subjective estimates are very important for both coach and athlete; it is desirable to note them in the athletes' diary and the coaches' logbook.

In conclusion, the common logic of training related principles of adaptation can be presented in the following sequence:

- Training at appropriate workloads evokes desirable reactions in athletes *(principle of stimulus magnitude*);

- This reaction induces an adjustment process, which results in increased work potential and more economic reaction to constant workloads (*principle of accommodation*);
- Increased working potential is utilized in sport performance in accordance with training results transferred from various exercises to the main competitive activity *(principle of specificity)*.

Contravening this linkage lowers the training effect, and the higher the athlete's level, the greater will be the expected impairment of the training effect.

1.3. Supercompensation principle and its application to practice

For a long time, both the theory and practice of sport training has sought a comprehensive, consistent explanation of how athletes' fitness and preparedness improve. In other words, the principal question was how sport training elicits gains in athletes' work capability. One of the first scientifically based answers to this question was offered in the mid 1950s by Soviet professor of biochemistry Yakovlev (1977), who reported the cycle of supercompensation after a single workout. This phenomenon was enthusiastically embraced by sport theorists who tried to explain medium- and long-term training effects basing on the supercompensation cycle. Further investigations and especially practical experience of high-performance training revealed many limitations in applying this principle to high-performance training. Despite this, the principle of supercompensation has again gained respect in interpreting and understanding training backgrounds.

1.3.1. Supercompensation cycle following a single load

The phenomenon of supercompensation is based on the interaction between load and recovery. The supercompensation cycle is started by the physical load, which serves as the stimulus for further reaction (Figure 1.6). The single load causes fatigue and acute reduction of the athlete's work capability, corresponding to the first phase of the cycle. The second phase is characterized by a pronounced process of recovery; consequently, the athlete’s work capability increases and reaches pre-load level at the end of this phase. Afterwards work capability continues to increase, surpassing the previous level and achieving the climax, which corresponds to the supercompensation phase. In the next phase work capability returns to the pre-load level.

Insert Figure 1.6 about here

This load-recovery pattern was proven many times using the example of exhaustion and the restoration of biochemical substances such as glycogen or creatine phosphate. Coaches using sport-specific tests can also detect the increased level of fitness within the supercompensation phase. Following the supercompensation theory several training concepts were elaborated that presupposed planning workout sequences in accordance with supercompensation phases after the preceding workout. This load summation in a workout series is a matter of special consideration.

1.3.2. Summation of several loads within a workout series

The initial interpretation of the supercompensation theory postulated a training design in which each new workout is performed during the phase of increased work capability after the preceding workout. Therefore, each workout causes a certain gain in the athlete's work capability. As a result of summation of a number of these gains, the athlete's fitness level constantly increases (Figure 1.7-A). If a subsequent workout corresponds to the fourth phase of the supercompensation cycle, when work capability returns to pre-load level, the gain evoked by the preceding load is not exploited and the fitness level doesn't rise (1.7-B). If each consequent load in the workout series is performed in the second phase, when recovery is still not complete, the athlete doesn't attain the pre-load level of work capability. As a result fatigue accumulates and fitness level decreases (1.7-C).

Insert Figure 1.7 about here

When these training load summations were published, the guidelines for coaching seemed very simple and comprehensive: workouts should be planned exclusively according to the supercompensation phases and fitness improvement would be guaranteed. However, it did not take long until coaches and scientists noted serious contradictions between the proposed "optimal" design and actual practice in high-performance training. The problem was in the duration of the supercompensation cycle. It was found and reported that the fatigue and recovery phases following a big workload last two-three days; thus, following supercompensation cycle two, a maximum of three workouts a week could be planned. This workout frequency is acceptable for novices and medium-level athletes but not for high-performance training, where athlete perform 6-12 workouts weekly. Some coaches tried to modify their training plans according to the theoretically favorable model and were quickly disappointed by the results of their attempts.

Of course, the necessity to wait for full recovery after each workout limited the opportunities to attain desirable load levels and reduced coaches' trust in the theoretical model. Several critical statements commented that high-performance athletes are accustomed to any load and no single workout, even if very intensive, will provide sufficient stimulus to achieve the desirable response. For this purpose a workout series with fatigue accumulation should be planned. Consequently, a modified scheme of the training load summation was offered (Figure 1.8).

Insert Figure 1.8 about here

The modified scheme of the training load summation proposes the accumulation of fatigue induced by several workouts; full recovery is done when the summarized loads achieve a certain level of stimulation. This renewed concept corresponds in general to high-performance sport practice and seems reasonable enough to comprehend. The main consequence of the proposed training design is that a number of workouts can be performed while the athlete is still fatigued. Moreover, even participating in competition can be planned for athletes that are not completely rested. This is very relevant to contemporary sport, because of the dramatic increase in the number of competitions during recent decades (see 4.1.3). Several competitions can not be scheduled for athletes after their full recovery and athletes perform in them as well as they can. However, special selected competitions defined as peak-events should be performed by completely rested athletes exploiting the supercompensation phase.

Let's summarize the above and see how it can be applied in practice.

- The supercompensation principle is basic for sport training, although it can not always be realized with regard to each individual workout.
- A training design entailing low workout frequency, as with novices and medium-level athletes, can attain the supercompensation phase after a single workout or a short workout series (two-three sessions).
- For high-performance athletes, a typical load summation presupposes a long workout series; consequently, the total time that high-performance athletes are within the supercompensation phase is relatively short and the periods in which they are not completely rested are relatively long.
- The supercompensation phase is a desirable state for achieving peak-performance; proper training design is necessary to select and prepare for the moments when this state are obtained.
- Several competition performances can be executed "below optimal load" when athletes do not reach the supercompensation phase; consequently, top performance in these competitions is usually not attainable.

1.4. Specialized principles of sport training

For a long time sport experts, coaches and experienced athletes have sought general rules to help them build rational athletic preparation. To this end, basic specialized principles of sport training should highlight the most relevant aspects and features of coaching and training. During the long period of sport evolution such principles were proposed and shared first in Eastern Europe (Matveyev, 1964; Harre, 1973) and later on the West (Dick, 1980; Bompa, 1984). Since this period big changes in sport reality have occurred. Nevertheless, consistent and comprehensive specialized principles of sport training are a necessary for rational practice. The following principles are presented in up-to-dated author's version, namely: specialization, individualization, variety, load interaction, and cyclical training design.

1.4.1. Specialization

Modern sport demands that athletes be very specialized and highly motivated to attain the main objective of long-term preparation – athletic perfection. At least three aspects of this specialization can be emphasized:

- specialization in society;
- specialization within different sports;
- specialization within a given specific sport.

Modern society gives respect and the opportunity to progress in various branches. Contemporary sport is widely recognized as an indispensable social phenomenon in the world. This phenomenon exists within a highly specialized sphere of interests, rules, norms, knowledge and even terminology. All persons involved in this phenomenon, and particularly high-performance athletes and coaches, carry out their distinct and very specific functions. Historically high-performance sport developed as the result of social and functional specialization; actually it exists as a highly specialized branch of human creativity and self-perfection.

The wide variety of sports available allows individuals to select the one in which individual interests and ambitions correspond most favorably to their personal, physical and mental predilections. Unlike common physical education and recreation, where amateurs engage in different sports for multilateral training, competitive, and particularly high-performance sport requires concentration on limited, highly specialized activities. Today's situation is relatively new. In an earlier stage of Olympic sport development, athletes were able to combine several sports. Some took part in the summer Olympics as cyclists and in the winter Olympics as speed skaters. The heroes of 1900-1924 combined weightlifting and wrestling, rowing and skiing, track and field and ball games. The natural evolution of competitive sport has eliminated this universality; the level of mastership desired for successful competition has become a barrier that only the highly specialized athletes can overcome.

The third aspect of specialization relates to the functional differentiation of sports events and disciplines within a given sport. This is particularly characteristic and important for novices and young athletes, which have to select the most appropriate discipline corresponding to their personal predisposition. The example of such specialization is a conscious selection of a proper discipline within a track and field program like running, jumping or throwing etc.

1.4.2. Individualization

Each athlete is an individual with his/her own combination of mental and physical abilities that dictate the athlete's development and progress. The coach's duty is to take the individual features of every athlete into account. In this regard the following coaching strategy can be employed:

- Recognize and emphasize individual merits – the athlete's features that give him/her advantages over other athletes;
- Recognize and possibly compensate for individual drawbacks - the athlete's features that work against him/her in comparison to other athletes;
- Find the appropriate event, discipline or individual style in which the athlete's specific merit-demerit combination will allow him/her to achieve the best results.

Several of the psycho-physiological characteristics that affect athletes' individuality of are presented in Table 1.7.

Table 1.7.
Characteristics affecting athletes' individual particularities
(table compiled with Dr. Boris Blumenshtein)

Characteristics	High border	Low border
Effect caused by training	High responder – training for certain period causes remarkable gain	Low responder – training for certain period causes minor gain
General tolerance to high workloads	High – the athlete can train hard and recover quickly after high workloads	Low – the athlete recovers slowly after high workloads and avoids them
Motivation	Stable and well defined – the athlete is aware of goals and complexity of preparation. Orientation to be a winner.	Unstable and not clearly defined – the athlete sometimes loses readiness to train hard, is not always focused on the goal
Self-regulation	High – the athlete is able to correctly perceive situations and adequately change his/her behavior and efforts; emotional control is sufficient.	Low – the athlete does not always perceive the situation correctly; can't adequately change psycho-physiological state; emotional control is limited.
Readiness to cooperate	The athlete is open for contact and collaboration with coach, partners and other experts; likes "team" work.	The athlete has serious limitations in collaboration with coach, partners etc.; usually avoids situations requiring trust in others.
Possibility of concentration	High – the athlete is able to concentrate on a given task and maintain this level for a while	Low –concentration level is insufficient and unstable, the athlete can't focus on a given task for a long time
Confidence	High – the athlete doesn't fear high stress in training and competition; trusts chosen way, training system and believes in success.	Low –the athlete fears high stress in training and competition; doubts that his/her preparation is correct and successful.

The personal characteristics considered in above table are relevant for any sport. The first two items touch on an athlete's general psycho-physiological potential. The differentiation between "high responder – low responder" dramatically affects the athlete's personality; usually low responders don't succeed in their preparation and can not reach the level of high-performance sport. Tolerance for high workloads varies greatly even among top-level athletes; the best athletes do not always have the highest level of tolerance for physical stress. In any case, this feature greatly affects the athlete's personality and preparation.

Motivation and self-regulation substantially determine the athlete's psychological status and his/her individual style of behavior. However, these features can be improved; they can be intentionally modified with the help mental training and a specially organized coaching program. Unstable and weak motivation to the point of low self-regulation can definitely become an insurmountable barrier to sport perfection. Readiness to cooperate depends on proper experience, general intelligence and psychological features related to intro-extraversion. As a rule extraverts are more attentive to external estimation, they are more dependent on social factors and usually prefer "team" work. Introverts are more oriented towards their own meaning and experience, and prefer to work individually. Consequently, extraverted athletes tend to be more cooperative, although introverts can change their behavior to meet specific situations. Of course, high motivation and self-regulation can increase the readiness of introverts to cooperate.

1.4.3. Variety

Variety of training stimuli is a result of the adaptation principle. The accommodation rule states: the more accustomed a stimulus, the lower an athlete's response is and, consequently, the lower stimulus for progression. Even common sense dictates an increase in training variety to make a preparation program more attractive. However, the nature of today's high-performance sport greatly restricts variety in the training repertory. The source of this limitation is specificity of training effect, i.e. the particularities of transfer of motor abilities and technical skills. Therefore, while variety of athletes' preparation is desirable and important, it should be attained within the accepted continuum of means, forms and training methods.

The ability to find variations within highly specialized preparation is an element of coaching creativity. However, several approaches to making such variations can be recommended (Table 1.8).

Table 1.8.
Sources of and approaches to enriching the variety of athletes' preparation

Sources of variation	How to get the variety	Examples
Renovation of exercises	Change usual rules and conditions. Employ unusual equipment. Lightening and/or loading the exercise	Change playing field size, number of players etc. Change of the weight of shot, discus, javelin, boat etc. Running downhill, running uphill, drafting in cycling, swimming and skating.
Modification of training method	Velocity (power) variation within a series and in sequential series Change the number of repetitions in sequential series Modify rest conditions within and between series.	Planning incremental and decremental series. Combination of long, medium and short series within one workout. Inserting low-intensity tasks, diverting activity etc. Use the elements of massage, stretching, muscle shaking…
Modification of the form of	Variation of team/crew roster Including competing stimulus in	Involving new partners. Formation of competing

organization	training. Adding other emotional stimulus	subgroups, giving bonuses. Invitation of parents, spectators, experts, media.
Variation of competition program	Competing in non-habitual events or disciplines. Competing in other sports.	Discipline variation within track and field program. Ski races for rowers, soccer game for runners or cyclists.
Changes in recovery program	Enriching repertory of recovery means. Adding attractions to day-off and vacation programs	Use of massage, hydrotherapy, physiotherapy, mental training Sightseeing tours, picnics, discothèque, fishing, horse-riding, diving etc.

As was already mentioned, exercise renovation is strongly restricted by specificity demands. Nevertheless, force, velocity and stamina requirements can be purposefully emphasized by means of appropriate measures. For example, lightening and simplifying an exercise facilitates higher speed, the use of additional resistance demands the application of greater force, etc. Similarly, modification of training methods makes it possible both to concentrate on a specific motor ability and to prevent excessive accommodation to very familiar exercises. For this purpose all load components can be varied and modified: intensity (velocity), number of repetitions, duration and rest intervals within and between series.

Varying the forms of organization give coaches additional possibilities for renewing their training program. Changing the team or crew roster helps to create a novelty effect; more experienced athletes can stimulate their partners' activity; levels of concentration and attention can be increased. Unusual emotional stimuli can substantially affect motivation and effort levels. This can be achieved by introducing competition into routine elements, giving bonuses for best performance, inviting competitors or spectators with emotional appeal and the media. All these measures are particularly relevant in the competitive period.

Competition is an obligatory part of preparation. It can be varied in two main ways: participation in additional events or disciplines and competing in other sports. Competing in additional events and disciplines is particularly popular in swimming and track and field; it is widely used especially in the preparation period in order break the monotony of routine exercises and to make the program more diversified and attractive. Competing in other sports is also typical for off-season and early season preparation. This can be associated with a general fitness program and tailored to athletes' individual interests. Another possibility is the use of trials in other sports for general fitness examinations. For example, long distance running and skiing trials are very popular among athletes from ball games, combat and endurance sports; free weight strength exams, like squats, power clean, bench press and bench pull are widely used in different sports.

It is important to note that applying the variety principle can differ according to the situation. The factors affecting its application are sport specificity; athletes' age, gender and experience; team or club finances and other considerations. Risk and safety factors should be also taken into account.

1.4.4. Load interaction

Generally speaking the training process can be expressed as the sequence of workloads. The athlete's response to several single workouts is determined by the following factors:

- the influence of the specific workout,
- the interaction of this influence with that of preceding workouts.

Certainly, both are determined by athletes' sensitivity to the workloads they perform. The fact to be emphasized regarding systematic training is that no single workout has a separate effect on the athlete; it always interacts with preceding workloads. Consequently, the present specialized principle of sport training postulates that each load, which is performed in a series with other loads, interacts with them; its effect depends on the influence of preceding workouts and conditions the influence of succeeding workouts. This load interaction is of great importance both for training planning and analysis. The possible types of load interaction are considered in Table 1.9.

Table 1.9.
Different types and examples of training load interaction

Types of interaction	Definition of interaction	Examples
Positive load summation	The load summarizes with the preceding load of a compatible modality and increases the accumulated training effect	A series of workouts with appropriate recovery breaks is planned to attain desirable load accumulation
Positive – recovery facilitation	The load facilitates recover after preceding workouts.	A small load aerobic workout enhances recovery after a highly intensive strength or anaerobic endurance workout.
Neutral interaction	The preceding load doesn't affect the subsequent workout	The subsequent workout is performed after a long recovery; influence of the preceding load is negligible
Negative – excessive overloading	The subsequent load summarized with previous ones causes excessive exhaustion	A series of high load workouts can cause chronic fatigue; high motivation in this workout series can be excessively tiring
Negative – response's deterioration	The subsequent load is not compatible with preceding one; its influence worsens the athlete's response and adaptation	An exhausting endurance workload aggravates recovery after a preceding workout for muscle hypertrophy, eliminating its effect

The importance of load interaction can not be underestimated. In fact, this factor determines the adaptation process as a whole and, therefore has an immediate influence on the effectiveness of the athletes' preparation. The importance and complexity of this problem is particularly prominent for high-performance athletes that usually execute 7-11 workouts a week. This means that each workout is superimposed on the residue of the previous workload. Moreover, even a single workout in certain sports can affect the combination of exercises for different training modalities. This combination can exploit positive interactions of different loads; sometimes training design ignores this factor and negative load interaction makes athletes' efforts useless. Of course, the mechanisms of different load interactions are very complicated. Nevertheless, in generally this factor can and should be taken into account (see Chapter 5).

1.4.5. Cyclical training design

This principle concerns the periodic cycles in athletes' training. Over a long period, the many components of long-term training repeat and return periodically. This order of compiling a training program is called *periodization*. At least four major factors determine these periodic changes in the character and content of training:

a) **Cyclical nature of nature**. Exogenous rhythms are among the fundamentals of organic life; seasons change as do day and night, determining all biological activities. Months and weeks naturally divide social and economic life into historical and traditional cycles that are incorporated into general life; the weekly vacation rhythm, for instance, is fixed throughout life. There is not doubt, then, that all biological, social and industrial activities are subordinated to exogenous rhythms of nature. It would be strange if sport were an exception.

b) **Adaptation as a general law**. As has already been stated, the law of adaptation determines athletes' training in general. Following this law, athletes should prevent excessive accommodation to habitual loads. Accustomed stimuli lose their effectiveness; in order to regenerate their adaptability, athletes should have training programs and exercise regimes that change periodically. In other words, excessively stabilized and fixed training programs lead athletes to an adaptation barrier, where they are forced to dramatically increase the magnitude of their habitual workloads to obtain the same results. From this viewpoint periodic change of the training program is a consequence of the law of adaptation.

c) **Sharing main tasks**. Serious training in any sport is characterized by complexity, diversity and variety; the main training tasks related to the development of general and sport specific motor abilities, technical and tactical skills, may be enormous in terms of magnitude and numbers. Obviously, all these tasks should be systematized and shared in time. It is well known, for instance, that certain technical skills should be based on the appropriate motor ability level. Accordingly, some basic work precedes more specific technical mastery; competition accomplishes this linkage and forms training cycles. Repeating such cycles periodically allows athletes to accomplish all the above tasks successively. Consequently, cyclic training design is the only possible way to provide a rational way to share main tasks.

d) **Competition schedule**. Each athlete's preparation is focused on certain competitions, which are held periodically. National and international sport federations as well as the International Olympic Committee oversee the frequency and timing of competitions. A typical schedule of competitions includes domestic and regional trials, national and international events, like continental and world cups and championships. Thus, schedule strongly determines the apexes of athletes' preparation and, consequently, periodic changes in the training program. A prominent example of such influence can be found in the Olympic Games; the quadrennial cycle of Olympic preparation is considered by National Olympic Committees as the most important periodic unit in long-term athletes' preparation.

All of the above shows that periodic training units or so called training cycles should form the basis for planning and analysis. Consequently, cyclical training design is one of the specialized principles of athletic training. Periodic training units were defined and utilized some time ago. One of the first systematic presentations of training cycles was done in the mid-1960s by Prof. Matveyev of the USSR (Matveyev, 1977). The basic principles laid out then remain relevant and useful to this day. Despite the variety of different sports, disciplines and events, periodic training units are using everywhere, even though several terms have been confused and used in conflicting manners. An up-to-date specification of periodic training units is presented in Table 1.10.

Table 1.10.
Hierarchy and duration of periodic training units

Time duration	Training units
Four years – period between Olympic Games	Quadrennial (Olympic) cycle
One year or a number of months	Macrocycle , may be annual cycle
A number of months as a part of the macrocycle	Training period
A number of weeks	Mesocycle
One week or a number of days	Microcycle
A number of hours (usually not more than three)	Workout or training session
A number of minutes	Training exercise

It is worth noting that all of the training units relate directly to appropriate parts of planning, where the training program, as the final product of this process, is compiled on the basis of the cyclic principle of training design.

Summary

Athletes' training is the primary component of *athletic preparation* that also includes competing and recovery. On the other side, *athletic preparation* contains physical, technical, tactical, psychological and intellectual preparations, which have their own tasks and particularities. The basic terms and concepts necessary for analysis and planning, i.e., goals, content, means and methods of training, are considered and commented on in this chapter.

The training related principles of adaptation elucidate the fundamental process of athletes' adjustment to training workloads. To recapitulate, three generalized factors - stimulus magnitude, exercise specificity and athlete's accommodation – determine responses to training and adaptation. The stimulus magnitude is regulated by training volume, training intensity and exercise novelty. These three load components are particularly important in light of the **overload principle,** which postulates that fitness gain requires stimulus magnitude to exceed the accustomed level. The specificity principle of training adaptation highlights the transfer of training results from one task (auxiliary exercise) to another (main exercise). There is training transfer of technical skills that is extremely important for movement perfection, and training transfer of motor abilities that determines the effect of any fitness program. Accommodation, as a principle of training adaptation, deals with the increase of work potential, where the athlete achieves higher levels of sport performance; and the decrease of athletes' reactions to a constant physical load, enabling them to deal with standard workloads more economically.

The supercompensation cycle as the most comprehensive mechanism of athletic fitness improvement elucidates the training process in view of the interaction between load, fatigue and recovery. The supercompensation principle was developed with regard to a single workout and to a workout series. According to this principle, the single load or sum of several loads evoke a phase of fatigue and recovery with a subsequent phase of increased working potential (supercompensation phase), which can be exploited for the administration of a new stimulus and to prepare for the next step in the progression. Despite a number of limitations and provisos, the supercompensation principle remains the basic one in training theory.

An updated version of the specialized principles of sport training are presented: (1) the principle of specialization relates to social aspects, selection of a specific sport for further perfection, and the determination of event-specific priorities; (2) the principle of individualization refers to psycho-physiological features of athletes; (3) the principle of variety deals with sources and particularities of training stimuli variation; (4) the principle of load interaction relates to positive, neutral and negative impacts within contiguous workouts; and (5) the principle of cyclical training design corresponds to and supports the general idea of training periodization.

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Chapter 2. Training effects

The follow-on outcomes of training sessions are *training effects*, which are the athletes' short-term and long-term responses to training loads. The effects should be the focus of special interest among coaches and athletes, who should know the desired effects from a given workout, training cycle, or more prolonged periods of training. This chapter is intended to summarize the concepts of training effects and to consider them for better understanding and more conscious planning and training control.

2.2. Training effects: General overview.

Training effects differ in terms of work duration and the consequences produced by completing the training. The types and particularities of training effects are presented in the following table (2.1).

Table 2.1.
The training effects (based on Zatsiorsky, 1995)

Types	Definition	Examples
Acute effect	Changes in body state that occur during the exercise	Heart rate increase; blood lactate accumulation; power reduction during exercise due to fatigue etc.
Immediate effect	Changes in body state resulting from a single workout or/and single training day	Increase in resting heart rate, urea and/or CPK level in blood; change of grip force, vertical jump, etc.
Cumulative effect	Changes in body state and level of motor/technical abilities resulting from a series of workouts	Maximal oxygen uptake and/or anaerobic threshold increase; gain in strength, endurance etc., gain in peak performance
Delayed effect	Changes in body state and level of motor/technical abilities obtained over a given time interval after a specific training program	Gain in explosive strength two weeks after cessation of highly concentrated power training program
Residual	Retention of changes in body	Retention of increased level of

effect	state and motor abilities after the cessation of training beyond a given time period	maximal strength a month after cessation of the specialized training program

Training effects are characterized by: (a) athletes' responses to workloads; (b) changes in athletes' state induced by training (work capacity, economization of body response, etc.); and (c) gains in sport-specific indicators (performance results, personal achievements) caused by training. The relations between different types of training effect are presented in Figure 2.1. The main relations are as follows:

1) The acute effects from several exercises form the immediate training effect of a single workout or training day;
2) The immediate training effects from a series of workouts join together to produce a cumulative training effect;
3) The cumulative training effect determines the athlete's preparedness and athletic performance.

In addition, there are two specific subtypes:

4) The delayed training effects, which occurs because of delayed transformation of the training stimuli into the performance change; and
5) The residual training effects referring to a period during which increased physical ability remains close to the level attained immediately after cessation of specific training.

Insert Figure 2.1 about here

In this chapter, we address the interactions between training effects later in the text after a more detailed discussion of each individual effect.

2.2. Acute training effect

As was already mentioned, acute training effects are the changes in an athletes' state occurring when performing a certain physical activity. Acute effects can be characterized by two groups of measures:

1) Indicators of training workloads (number of repetitions, mileage, number of lifts, bouts, jumps, throws, etc.) targeting sport-specific abilities;
2) Physiological variables, characterizing athletes' response to performed workloads such as blood lactate (BL) levels, heart rate (HR), blood pressure, galvanic skin response (GSR), rate perceived exertion (RPE) e.g. according to the Borg scale (Borg, 1973), change in the body temperature, sweating intensity, and/or oxygen uptake (in lab conditions).

The first group of measures has been used widely over the years, especially in measurable sports, although they have been favored in non-measurable sports as well. The second group of indicators needs appropriate instruments (e.g. Polar watch, BL monitors etc.) which have become increasingly popular among practitioners of many sports. On-line monitoring of athletes' state offers coaches more accurate control of acute training effects. These advanced technologies facilitate regulation of physical load levels based on HR and BL, and of emotional stress, by means of GSR and RPE.

2.2.1. Acute training effect assessed by sport-specific indicators.

Monitoring of sport-specific characteristics allows coaches to regulate dose-response ratio and facilitates attainment of the desired acute training effect. As an example, recording velocity or performance time is extremely important in exercises for developing maximal speed. An optimal dose in such workouts is conditional upon the number of repetitions (runs, swims, bouts etc.) performed at a velocity that approaches individual's maximum.

Case study. A team of experienced soccer players performed typical exercises for maximal speed improvement: ten repetitions of 20-m dribbling with five ball-touches performed at maximal speed, the inter-bout rest intervals were 1.5 min. The best average performance was achieved on the third repetition; near peak-performance level was maintained until the 7th repetition (Figure 2.2). Other bouts were slower by more than 0.4 s (10 % corridor). This means that the planned dose for the whole team was excessive. The individual dosage should vary between six and eight repetitions based on the performance results. (Mark Tunis, 2005, personal communication).

Insert Figure 2.2 about here

Another example of how sport-specific information makes it possible to find optimal acute effect can be illustrated in endurance training. The acute effect of prolonged endurance exercises can be controlled by monitoring average velocity and movement rate during performance. Coaches usually prescribe the velocities that athletes should maintain throughout the exercise. Real-time indication of the movement rate facilitates recognition of earlier, admissible and excessive fatigue and based on these data the desired acute effect can be obtained. Let's consider the possible relations between velocity and movement rate (MR) resulting from acute effect regulation (Table 2.3.)

Table 2.3.
Acute training effect assessed by velocity and movement rate (MR) during endurance workout

Phase	Relations between velocity and MR	Comments
Stable performance	Maintaining velocity and MR at the same level	Stable movement technique. This work duration is suitable for interval training
Moderate fatigue	Velocity is maintained at the same level - MR increases slightly	Such a work duration is suitable for aerobic endurance training
Hard fatigue	Velocity is maintained at the same level - MR increases substantially	Such a work duration is suitable for anaerobic and mixed training
Excessive fatigue	Velocity decreases, MR increases or decreases	Not suitable for any training goal

It is known that continuous work with constant speed can be subdivided into four phases (Farfel, 1976). The first phase is the most prolonged; during this phase the athlete keeps planned velocity and stable MR, indicating habitual technical pattern. This phase can last one hour and even more if the work intensity is below the anaerobic threshold and can continue 15-40 min when intensity is at the anaerobic threshold level (marathon racers can maintain such an intensity longer). However, when the exercise intensity surpasses the anaerobic threshold, the duration of this phase shortens.

The second phase is characterized by maintenance of velocity at a stable level and a moderate increase in MR. This pattern indicates a reduction of force application that is compensated for by an appropriate increase in movement frequency. Duration of this phase can vary from 30 s to 3-5 min and depends on exercise intensity. This phase can be effectively exploited in exercises to enhance aerobic endurance; in this case athletes approach anaerobic threshold level, thus stimulating an increase of "aerobic velocity".

The third phase is characterized by speed maintenance that is provided by a pronounced and excessive increase of MR. This response indicates a drastic reduction of force application, which is compensated for by higher movement frequency and often by technique impairment. Usually this phase leads to a dramatic activation of anaerobic metabolism as well as to blood lactate accumulation; its duration usually varies from 30-60 s. This phase is not desirable in aerobic endurance workouts because it activates anaerobic metabolism and has a deleterious effect on preceding aerobic work. However this phase can be exploited in aerobic-anaerobic exercises, where the terminal blood lactate increase can be desirable and planned.

The fourth phase indicates the athlete's inability to sustain previous speed despite extreme efforts. An MR increase indicates a further attempt to prevent speed decrease; an MR reduction shows a failure of such an attempt. This phase of excessive fatigue should be prevented and, as a rule, excluded from training and competitive practice.

2.2.2. Acute training effect assessed by psycho-physiological variables.

Monitoring psycho-physiological variables makes it possible to control levels of physical and emotional stress and, simultaneously, to obtain desirable acute training effect**.** HR and BL monitors are widely used instruments that help to effectively monitor metabolic levels of performed workloads.

Case study. A highly-trained kayaker performed progressive interval training: three series of three bouts of 1min work and 1 min rest; recovery intervals between series were 5 min. Workload increase was regulated by stroke rate, which was measured by the coach; acute training effect was assessed by heart rate that was recorded constantly, and blood lactate that was taken during the third minute after each series (Figure 2.3.). The data obtained reveal that physical stress increased progressively during the exercise and reached the level that indicates pronounced mobilization of anaerobic energy supply, as was planned. In addition, load regulation during exercise was effective enough and the athlete was able to obtain incrementally increasing responses (Issurin, Timofeev and Zemliakov, 1989).

Insert Figure 2.3 about here

Unlike conditioning training in which athletes focus on developing their motor abilities, technical and techno-tactical workouts often elicit emotional strain that produces a specific acute effect. The universal practical approach to assessing emotional tension is based on the measurement of Galvanic Skin Response (GSR). Ordinary GSR levels are very individual; emotional excitation causes a decrease of GSR value; an increase indicates emotional fatigue that is typical of prolonged strenuous workouts. Therefore, tasks requiring high excitation (maximal speed bouts, explosive efforts etc.) can be effectively monitored by means of GSR.

Case study. GSR values were measured in highly qualified basketball players during a stressful workout. Emotional tension increased progressively during warm-up and the performance of techno-tactical drills; this was reflected in a decrease of GSR (Figure 2.3). The training game (1st half) elicited maximal emotional tension that decreased during the break and increased again at the beginning of the 2nd half. However this high level of emotional excitation was not maintained till completion of the game and GSR increases indicated pronounced emotional fatigue. The cooling down caused a further decrease of emotional tension that reached ordinary levels at the end of the workout. It can be hypothesized that the acute training effect of such a workout could have been higher if the coach had been able to maintain emotional excitation near maximum (for this game level) for a more prolonged period (Dr. Boris Blumenshtein, personal communication, 2004)

Insert Figure 2.4 about here

2.2.3. Programming of acute training effects.

Are acute training effects really manageable? In other words: are athletes' responses to a workout predictable and controllable? The answer is – not always and not completely. The question that follows is: how can we make athletes' responses more predictable? It is obvious that complete control in each workout is presently unobtainable, but some progress in this direction is desirable and possible. Very often coaches think that experienced athletes do not need special task clarification prior to performance as well as post-exercise evaluation. Athletes do not always receive brief clear hints during drills that can stimulate their motor output. However, formulating the goals and systematic exchange of information with the athlete (a 'programming algorithm') facilitate the attainment of desirable acute training effects. An example of such programming is presented in Table 2.4.

Table 2.4.
Programming the acute training effect

Operation	Example	Remark
Goal setting	Developing maximal speed	This is the most important exercise in a workout

Determining performance conditions	Work-rest ratio, number of repetitions and sets, velocity regimes, rest conditions	Short and clear explanation, objective measurable indicators are desirable
Focusing on specific (individual) demands	Targeted movement rate, technical and/or tactical tasks	Demands of special importance are emphasizing
Performance control	Visual and instrumental control, performance correction, motivation	Giving the most important information that affects ongoing performance
Self-report taking	The athlete tests his/her performance reserves	This operation is not always necessary
Evaluation	Correspondence to demands, individual remarks	Positive emotional conclusion is desirable

Acute effect programming presupposes a number of operations that specify the goal, performance conditions, specific demands, performance control and post-exercise evaluation. The initial operation is goal setting: the exercise goal should be clearly and briefly transmitted to athletes; it is likely that the athletes will know which output is expected. Relevant performance conditions should be determined and specified using objective and quantitative indicators like planned velocity, MR, expected HR etc. It is important to focus athletes on one-two specific demands (athletes can not control more than two demands), which are of special priority for certain athletes. For instance, an athlete can be asked to keep in mind some individually important technical detail (i.e. effective take-off, or relaxation in recovery phase), special tactical task (i.e. accentuated start, uniform performance) or other sport-specific demand. Using appropriate instruments (HR monitor, MR indicator, stopper) to monitor the current performance coaches can correct athletes' behavior and eliminate mistakes. Timely remarks assist in keeping high motivation for better performance. Post-exercise self-reports can improve cooperation between coach and athletes and encourage the latter's' self-control. The final evaluation should be specific and be limited to one-two sentences. It is likely that this conclusion will have a positive emotional impact.

2.3. Immediate training effect

As defined above (Table 2.1), immediate training effect are the changes in body state induced by a single workout or/and by a single training day. The immediate training effect arises as a result of summation of acute training effects from several exercises. As a rule a single workout and a single working day in high-performance athletes include one or two dominant training modalities; the reason is that athletes cannot respond to many stimuli acting simultaneously on many targets. However, the training sessions of low-level and medium-level athletes can include more diverse exercises. Consequently, the immediate training effect can be more *selective* when a workout is concentrated on a specific ability; or more *complex* and combined if the workloads are aimed in many different directions.

2.3.1. Indicators of immediate training effect

Evaluation of the immediate training effect is an essential part of the coaching routine. Usually the coach's assessment is based on subjective estimation of performance, the current results of several measurements (performance time, HR etc.) and visible signs of fatigue and readiness for further workouts (Table 2.5).

Table 2.5.
Indicators of immediate training effect

Characteristics	Indicators
Total amount (‘volume’) of training load per session/day	Total mileage, mileage of intensive exercises; number of lifts, throws, stunts; net-time of playing ball games, etc.
The athlete’s subjective response	Sleep, appetite, general activity, muscle soreness, level of fatigue, willingness to train, etc.
Objectively measured athlete’s response	Resting HR after awaking at the morning; results of the biochemical analyses: blood urea and CPK in the morning after a working day; changes of test results (grip force, standing vertical jump etc.), body weight etc.
The coach’s pedagogical estimation	Correspondence of executed work to training program: completely corresponds, mostly corresponds, far from complete, failure of daily program.

Let’s consider the data presented in table 2.5. Sport-specific indicators of performed workloads give primary objective information. Indeed, all measures of athlete response have value as feedback on training stimuli. Very often the total amount of performed exercises (total mileage, number of lifts, throws etc.) gives the ultimate indication – the athlete completed the planned workload.

Examination of athletes’ **subjective responses** is the most readily available, cheapest and informative way to characterize immediate training effects. The subjective estimates used most widely usually pertain to sleeping, appetite, general activity and willingness to train. Muscle soreness is not employed so often for self-estimation; nevertheless it appears very often following big workloads or the juxtaposition of several workouts. Delayed muscle soreness is particularly strong after several types of exercises especially those with a pronounced eccentric component like downhill running, yielding actions, drop jumps etc. Even body weight trends can provide a relevant indication, particularly in sports divided into weight categories.

Several **objective variables** of athletes' response have been adopted in different sports, the most widely used indicators of immediate training effect being resting HR, blood urea and CPK. Resting HR is one of the simplest and most practical of the accepted modes of monitoring athletes. Basal HR level should be obtained from a well rested athlete in bed immediately after a night's sleep. When HR corresponds to basal level or increases less than 6 bpm (beats per minute) this indicates good recovery; when HR increases more than 6 but less than 10 bpm – this usually reflects sufficient adaptation but considerable fatigue; an HR increase of 11-16 bpm indicates a high level of fatigue; an increase of more than 16 bpm shows excessive fatigue and should serve as an alarm signal.

Blood urea and creatine phosphokinase (CPK) are usually measured in blood samples taken from athletes before breakfast and after 12 hours of fasting. Blood urea is used to estimate metabolic fatigue and metabolic recovery; it serves as an indicator of protein metabolism and increases particularly after long-duration endurance exercises or highly intensive strength workloads (Viru & Viru, 2001). For a long period this indicator was used especially in endurance sports to prevent overtraining. CPK as a blood enzyme reflects the level of muscle tissue breakdown, which is particularly suitable for combat sports and explosive strength exercises such as throws, jumps and shot put. On the other hand, the considerable damage of muscle fibers that occurs during marathon running also causes an increase in CPK level (Wilmore & Costill, 1993). Compared with other indicators, CPK is extremely variable; its levels after highly intensive or combat exercises can reach three to four times the basal values.

Besides the above-mentioned physiological indicators there are a number of variables indicating athletes' response with regard to the neuro-physiological and sensory systems. For example, time reproduction and force differentiation can be measured to evaluate neuro-physiological reactions induced by highly coordinative training that includes learning and perfection of technical skills.

The coach's pedagogical estimation is the last but not the least important for evaluating immediate training effect.

2.3.2. Monitoring immediate training effect

Employing objective scientific indicators facilitates better evaluation and control of immediate training effects. At the same time, the use of simple practical-indicators also can improve the quality of training (Table 2.6).

Table 2.6.
Four-component scale for monitoring immediate training effects

Component	Points	Clarification of evaluating state
Resting HR after night's sleep	4 3 2 1	HR increases 0-6 bpm HR increases 7-10 bpm HR increases 11-16 bpm HR increases more than 16 bpm
Fatigue-restoration state	4 3 2 1	Full restoration, lack of fatigue Sufficient restoration, slightly fatigued Partial restoration, substantial fatigue Poor restoration, very fatigued
Willingness to train	4 3 2 1	Strong willingness to train Medium willingness to train Poor willingness to train Lack of willingness to train
Coach's estimation of training day	4 3 2 1	Completely corresponds to daily program Mostly corresponds to daily program Does not correspond enough to daily program Failure of daily program
Total score	4-16	Integrative estimation of training day

Case study. Immediate training effect was monitored during a 20-day training camp of high-level athletes (canoe-kayak paddlers); each single day was estimated by means of the four-component scale. Every morning the athletes measured their resting HR in the bed after the night's sleep; then, in the lobby of hotel they completed the self-estimation forms, in which they were asked to evaluate their "fatigue-restoration state" and "willingness to train"; the coach gave his integrative estimation of the previous day's work. The entire four-component evaluation scale provided a total estimate of the previous day of training. After preliminary instructions and approval the evaluation procedure took one-two minutes for each athlete; individual current data were plotted on the day-by-day graph. The graphs of two selected athletes show deviations in their current state as a response to the previous day's work (Figure 2.5). When the total score decreased to the critical level (indicated by triangles) individual training programs were corrected. The training camp was followed by an international competition in which all the participants attained their best performance.

Insert Figure 2.5 about here

In conclusion, immediate training effect incorporates many-faceted and multilateral changes in athletes' body state; these changes affect their readiness and sensitivity to ongoing workloads and, correspondingly, determine short-term training planning.

2.4. Cumulative training effect

In terms of competitive sport, the cumulative effect of long-term training is the primary factor which, to a great extent, determines an athlete's success. Cumulative training effect can be reflected by two groups of indicators:

- Physiological and biochemical variables, which characterize changes in the athletes' condition, and
- Variables of sport-specific abilities and athletic performance, which characterize changes in the athletes' preparedness

The following section addresses the cumulative training effect assessed separately by physiological variables and by estimates of several motor abilities.

2.4.1. Improvement rate in physiological variables

Functional limits of different physiological systems cannot be increased to the same extent. Therefore, various physiological indicators of cumulative training effects vary within their appropriate range. Table 2.6 summarizes the findings on changes in the most revealing physiological indicators induced by long-term systematic training. Of course, cumulative training effects are strongly influenced by the workloads. For instance, development of the maximal strength typical for weightlifters does not stimulate an increase of aerobic enzymes and maximal oxygen uptake; conversely, endurance training does not enlarge muscle mass. Nevertheless, the data displayed here allow comparing possible changes of physiological functions resulting from appropriate training.

The most pronounced changes can be obtained in aerobic abilities. More specifically, long-term endurance training can induce an increase in aerobic enzymes of up to 230% (Volkov, 1986). Similarly, mitochondria count, myoglobin content and muscle capillarization increase dramatically. As a result, maximum oxygen uptake can be improved remarkably, although data from genetic sport studies indicate that this measure is strongly controlled by heredity (see 3.1).

Unlike aerobic ability determinants, the characteristics of anaerobic metabolism can be improved to a lesser extent. This applies to anaerobic enzymes and particularly to peak blood lactate, whose increase is relatively small even when training is highly intensive. Creatinphosphate storage as an important factor of maximal speed ability improves slightly as a result of endurance training (about 12%) but can be increased greatly by means of sprint training (up to 42%).

Cardiovascular system measures strongly determine motor output in both aerobic and anaerobic exercises. Indeed, maximal cardiac output increases 50-75% but this improvement is caused by stroke volume increase with almost no relation to maximal heart rate, which tends to change very little.

Insert Figure 2.6 about here

Pronounced changes also occur in the musculoskeletal system, e.g. muscle mass increases by 10-40%. Large gender differences exist with regard to this matter (see 3.3.). Muscle fiber size can be increased in similar proportion, however the enlargement of fast and slow fibers is different, with fast fibers having greater hypertrophy than slow ones (Thorstensson, 1988).

The above data characterize long-term cumulative training effects of many years of training. The improvement of physiological variables varies depending on the age and qualification of athletes. Table 2.7 presents data summarizing seasonal changes in various indicators. Top-level soccer players and runners did not register any progress in their physiological capabilities despite very serious professional preparation. At the same time younger athletes with less previous experience considerably improved their physiological functions and, recorded more favorable cumulative training effects. It is likely that aged elite athletes reach a plateau in their physiological capabilities and continue preparation near the upper boundaries of their biological limits. However this doesn't means that their cumulative training effect is negligible; they can enhance their performances thanks to better technique, tactics and mental benefits (see 7.3.x). On the other hand younger and less experienced athletes enable respond more effectively to training stimuli and manifest more pronounced physiological progress.

Table 2.7.

Seasonal changes of physiological variables in athletes of different qualification

Sampling and training span	Assessed variables and effects	Source
Professional	Maximal anaerobic power, anthropometric	daSilva et

Brazilian soccer players (n=20)	measures and body composition didn't change	al., 2001
Elite junior soccer players (n=9)	VO_{2max}, lactate threshold and running economy improved by 10.7, 15.9 and 6.7% respectively	Helgerud et al., 2001
Elite middle- and long distance runners aged 25.5 yr (n=17)	Insignificant decrease of VO_{2max} and minor increase of athletic performances over a 3-year period	Legaz Arreze et al., 2005
Medium level runners aged 18.5 yr (n=21)	VO_{2max} and anaerobic threshold velocity improved by 4.1 and 1.94% respectively	Tanaka et al., 1984

2.4.2. Improvement of motor abilities

Unlike physiological measures, which require special instrumentation and skilled personnel, testing of motor abilities can be and is executed as a part of training routine by coaches themselves. Changes in the results of motor tests allow evaluating cumulative effects of training programs. The range of changes induced by training depends on many factors such as age, athlete's individual predisposition and qualification, training methods and means, but first and foremost it depends on the biological nature of specific abilities..

Example. Imagine an athlete who is striving to improve his maximal speed ability. Everyone knows that progress in this fitness component is very limited. Based on the data presented in Figure 2.7, the major reason of this limitation is low improvement of corresponding physiological variables that determine maximal speed (anaerobic enzymes, creatinphosphate storage, and peak blood lactate). Moreover, this ability is strongly predisposed by heredity (see 3.1). As a result, any small progress in speed drills can be viewed as a serious achievement.

The opposite situation exists with regard to muscle endurance, where progress is due to pronounced changes in aerobic metabolism and the musculoskeletal system. Thus, 15-16 years schoolboys can double their performance in pull-up tests after two months of systematic training. Improvement rate in typical aerobic exercises can be also very impressive thanks to huge increases of aerobic enzymes, myoglobin mass, number of mitochondria and muscle capillarization. In addition, large improvements are associated with higher movement economy, due to better energy utilization and better sport technique.

Increase of maximal strength is affected by two general factors: improvement of the neural mechanisms of muscular control and muscular hypertrophy. The contribution of these two factors to the cumulative effect of strength training differs greatly for experienced athletes and novices: the latter can improve their maximal strength relatively fast thanks to bettering of neural mechanisms and, simply stated, learning the technique; qualified athletes improve their strength mostly at the expense of muscular hypertrophy (Klausen, 1991). On the assumption that relative muscle mass can be substantially increased (Figure 2.6.), this means that athletes (even females) can attain remarkable muscle hypertrophy.

Another point to keep in mind is that while the long-term cumulative effect of explosive strength training. This ability depends on maximal strength, which can be improved quite a lot. But it is also affected by maximal speed factors, whose improvement is very limited. Consequently, improvement of explosive strength measures is less than for maximal strength but higher than for maximal speed traits.

Insert Figure 2.7 about here

2.4.3. Improvement of athletic performances

Throughout a long athletic career, athletes strive to improve their athletic performance. From the data presented above, it can be seen that positive changes are usually the outcome of the cumulative effects of preceding training. Of course, it would be highly desirable to offer norms and criteria for cumulative training effects over a given period. This is indeed possible in sports with measurable results where athletes' achievements can easily be recorded. Unlike ball games and combat sports, in these sports measuring time, distance or weight lifted allows objectively evaluating performance gains over given time periods. Table 2.8 displays examples of annual performance gains for different sports and ages.

Table 2.8.

Annual performance gains of gifted youngsters and elite athletes

Discipline	Athletes' category	Performance gain per year, %	Source
Swimming, 50-200 m	Gifted boys, 12-13 y	6.1 – 6.5	Rahmentrainingsplan DDR, 1989
Swimming, 50-200 m	Gifted boys, 16-17 y	1.2 - 2	Rahmentrainingsplan DDR, 1989
Swimming, all events	Australian and USA Olympians	1.0	Pyne et al., 2004
Running, 800 m - marathon	Sub-elite runners, aged 22±4.4 y	1.05	Legaz Arreze et al., 2005
Olympic weightlifting	Gifted boys, 17-18 y	14.7 - 15	Roman, 1986

Olympic weightlifting	Elite athletes, body weight 60 kg and more	1.03 – 1.07	Roman, 1986
Kayaking, kayak-single 500 m	Gifted boys, 13-14 y	12 – 13.2	Sozin, 1986
Kayaking, kayak-single 500 m	Elite juniors, 17-18 y	2.2 – 2.7	Sozin, 1986
Canoe -Kayak, single 500-1000 m	USSR National team, 23±3.1 y	0.6 – 2.5	Issurin, 1994

Despite the specificity of different sports noted in Table 2.8, the average performance gains of elite adult athletes are within a very narrow range ; namely - 1-1.07% (The data of elite senior canoe-kayak paddlers exceed this range but this is conditioned by production of improved boats and paddles). In fact, each aging athlete during a long-term sport career approaches his/her biological limit when further progress becomes impossible, but this does not mean that these athletes discontinue their preparation.

Example. A group of high-level middle- and long distance runners aged 25.5 years on average was studied over a period of three years. Purposeful systematic preparation resulted in very small and insignificant performance improvement (Legaz Arreze et al., 2005). Presumably, these aged experienced athletes reached their biological limits of event-specific progress. On the other hand, training method insufficiency can not be excluded.

Thus we can see that improvement rate of athletic performances gives extremely important and valuable information for evaluating cumulative training effect. However, sports in which performance cannot be objectively evaluated and in aging athletes approaching their biological limits, this evaluation has serious restrictions. For these athletes monitoring of physiological variables and motor fitness measures is of particular importance.

Concluding remarks

Two phenomena are important for the cumulative training effects:

- Continuity of the training process; and
- Heterochroneity of the training process.

Continuity of the training process is typical for contemporary competitive sport. Avoidance of interruptions in training is of primary importance both from the viewpoint of training methodology and exercise physiology. Interruptions caused by injuries and illnesses are regrettable, but interruptions due to deficit of motivation or willpower are even more so. The possible negative consequence of such interruption is the failure to adapt when flexible and precise interactions within and between physiological systems are disrupted. At the same time, the continuous nature of athletes' preparation emphasizes the importance of recovery phases, which should be specially planned as part of the framework of weekly, monthly and annual preparation.

Heterochroneity of training, as a principal point, means that various physiological systems and diverse functions have different rates of proper development during training and different rates of detraining after the cessation of training. The heterochronous changes of physiological and motor functions elicit two principal consequences, which determine special types of cumulative training effect:

1) The peak values of several functions and sport-specific achievements do not always coincide with the final phase of appropriate training programs; sometimes a temporal delay is necessary to obtain the maximal response. This type of cumulative effect is called the *delayed training effect;*
2) Long-lasting training is intended to develop many motor abilities; they remain at an increased level during a certain period after training cessation. This retention belongs to the domain of cumulative effect and forms, in fact, another special type of training effect called *residual training effect*.

2.5. Delayed training effect

Usually we expect that training effect achieved is synchronized with the ending phase of the training cycle. Indeed, acquisition of a new technical skill follows intensive improvement of movement technique and considerable enhancement of athletic performance. However, when the training program causes pronounced morphological and physiological changes, athletes need a period in which the long-lasting biological adaptations occur after which the athletes attain a new qualitative level. Therefore, training performed during a given period does not always produce an effect that is synchronized with workloads. Moreover, athletes frequently need a period for recovery after highly intensive workloads. In these cases, the performance gains occur after some delay, a period of *delayed transformation*. When this temporal delay is relatively short (several days) we call it a usual cumulative effect, however, when the delayed transformation requires a more prolonged period (a week and more) this outcome qualifies as a *delayed training effect.* This differentiation can be important for planning and comprehension. One of the researchers conceptualized the delayed training effect was Verhkoshansky (1988) who found this phenomenon with regard to peak power performance. In general, delayed training effect is conditioned by the sequencing of two training phases: the loading phase that provides athletes with massive exhaustive workloads, and the realization phase that creates favorable conditions for restoration and, possibly, achieving a state of supercompensation (Table 2.9).

Table 2.9.
The general characteristics determining delayed training effect.

Characteristics	Loading phase	Realization phase
Training volume	High	Medium - low

Training intensity	Medium – high	High
Workload character	Highly concentrated specialized workloads	Event specific specialized workloads
Fatigue-restoration ratio	Unfavorable, athletes are mostly fatigued	Favorable, athletes are usually well rested
Duration	4-8 weeks	1-4 weeks

The delayed training effect is particularly relevant for motor abilities, which are more sensitive to fatigue accumulation and where maximal performances demand highly precise neuro-muscular movement patterns. This category includes maximal speed, explosive strength exercises and maximal strength performances like lifting 1RM.

Case study. An eight-week training of high-level swimmers was studied. During the initial six weeks, swimmers executed extensive swimming program (7-10 km per day) and three-four fitness workouts per week devoted to swim-specific strength endurance and swim-specific stroke power. The logic of this combination was based on the fact that extensive swim training and strength endurance exercises suppress peak power while dry-land power exercises prevent an unfavorable decline of explosive strength. In fact, explosive strength slightly increased at the first mid-exam and significantly decreased at the second one (Figure 2.8). At the same time swimmers' strength endurance enhanced considerably. During the last two weeks prior to the competition the program was changed: the swimming volume was reduced to 4-6 km per day; the strength endurance and explosive strength fitness program was replaced by calisthenics, flexibility and relaxation routines. The final test revealed retention or a slight reduction of strength endurance while explosive strength ability improved dramatically. Therefore, the delayed training effect occurred with regard to explosive strength and not strength endurance. (Issurin, 1986; unpublished data)

Insert Figure 2.8 about here

The major factor determining delayed training effect is the contrast of load magnitude and fatigue-restoration ratio in the two sequencing phases. Simply stated, fatigue accumulation is the reason why the cumulative training effect was not obtained when the loading phase was completed. The drastic workload reduction in the realization phase activates recovery processes; athletes' body obtains sufficient energy supply to complete the adaptation process and this is an important condition for preparedness improvement during the realization phase.

Special attention should be paid to the duration of the temporal delay in the training effect obtained. This duration is conditioned by two major factors: (1) the period desirable for full recovery after prolonged loading phase; and (2) the time span necessary to complete the biological adaptation following heavy workloads in the preceding phase. Taking into account both these factors, the temporal delay is usually in a range of 1-4 weeks. Some coaches and researchers have reported longer delays. It is highly probably that these delays can be attributed to the superposition of a delayed effect with the cumulative effect of the later training.

2.6. Residual training effect

The concept of residual training effect is relatively new and less known than other types of training outcomes. This section summarizes the most recent information about this matter.

2.6.1. Basic concept and types of residual training effects

As already stated, long-term adaptation to physical workloads includes appropriate changes the morphological and functional levels. Obviously, changes in muscles, tendons and bones induced by many years of strength training are retained for long periods. Similarly, changes elicited by endurance training remain for a considerable time although they are not as visible as the consequences of strength work.

Example. Imagine a person who was a qualified weightlifter ten years ago. Can you recognize that he was a weightlifter? Very likely. The morphological adjustments induced by many years of weightlifting training are retained long after the sport career has ended. Moreover, some of these changes (skeletal transformation, for instance) are not reversible and remain throughout life. Another example: highly concentrated sprint training causes a remarkable increase in creatinphosphate capacity, which is retained at the acquired level for several days after cessation of training. Thereafter it decreases over a two-three week period until it returns to previous levels. Both cases are examples of residual training effects, but the first relates to long-term training residuals, while the second to short-term training residuals. Both examples are based on changes in material substances but the nature and attribution of these alterations are very different; correspondingly the timing of these processes also differs.

Initially the general approach to “training residuals” induced by “residual effects of training” was conceptualized by Brian and James Counsilman (1991) and focused mainly on the long-term aspects of biological adaptation. They reasonably proposed the existence of long lasting training residuals as an important background element of training theory. From the viewpoint of general adaptation and long-lasting sport preparation, long-term training residuals are extremely important. In fact, the obvious differences of body types, composition and proportions between runners and wrestlers, swimmers and rowers etc. are determined by both selection and long-term adaptation. Consequently, visible differences in bone hypertrophy and muscle topography are conditioned by long-term training residuals. However, for training program design, short-term training residuals are of primary importance. Analysis and further examination of training residuals (and correspondingly, residual training effects) lead to their classification into three separate types: long-term, medium-term and short-term training residuals (Table 2.10).

Table 2.10.

Training residuals: types, attribution and rate of loss (Issurin,2003)

Types	Attribution	Changes in the athletes' state	Rate of loss
Long-term residuals	Musculoskeletal system	Skeleton adaptation: morphological transformation of bones and joints	Partly not reversible changes
		Gross somatic adaptation of muscles, formation of specific muscle topography	A number of years
	Neuromuscular system	Acquisition of gross coordination, movement skill and event-specific technique	A number of years
	Cardiovascular system	Heart hypertrophy: size and volume; diameter of aorta	A number of years
Medium-term residuals	Cardiovascular and respiratory system	Increase of capillary density, resting heart rate, resting stroke volume	A number of months
	Neuromuscular system	Improvement of muscle effort regulation: muscle fiber recruitment, force differentiation, sport-specific balance etc.	A number of months
Short-term residuals	Peak metabolic productivity - aerobic	Increased anaerobic threshold, increased aerobic enzymes and muscle glycogen storage	A number of weeks
	Peak metabolic productivity - anaerobic	Increased anaerobic alactic and glycolitic power, capacity and efficiency	A few weeks to a few days
	Neuromuscular system	Increased muscular strength, power and size	A number of weeks
		Increased muscular endurance	A few weeks
		Flexibility	A few weeks

While a training program prescribes hard work for a given period to develop a specific motor ability; the duration of training residuals determines the period during which this ability still remains at the desired level. After training program cessation the developed motor abilities decrease and their rate of loss should be taken into account. Many factors affect short-term training residuals.

Case study. Highly qualified soccer players performed four weeks of fitness training that included large amounts of intensive exercises for muscular strength and strength endurance. As a result the athletes exhibited a tremendous improvement in the appropriate fitness measures, e.g. a more than six-fold gain in repetitions of abdominal curl-ups (Figure 2.9). However this performance began to decrease immediately after the fitness program ceased. After two weeks of detraining the strength endurance measure was still two-fold higher than at the pre-training level. It can be assumed that training residuals after a highly concentrated strength endurance training program in soccer players last approximately two weeks and after that drop dramatically (based on Bangsbo, 1994).

Insert Figure 2.9 about here

2.6.2. Factors affecting short-term residual training effects

Five factors affecting the duration of short-term training residuals are considered below (Table 2.11).

Table 2.11.
Factors affecting the duration of short-term training residuals
(based on Hettinger, 1966; Counsilman & Counsilman, 1991; Zatsiorsky, 1995)

No	Factors	Influence
1.	Duration of training before cessation	Longer training causes longer residuals
2.	Load concentration level of training before cessation	Highly concentrated training as compared with complex multi-component training causes shorter residuals.
3.	Age and sport career duration of athletes	More aged and more experienced athletes have longer residuals
4.	Character of preparation after cessation of concentrated training	Use of appropriate stimulatory loads allows prolonging residuals and prevents fast detraining.
5.	Targeted abilities.	Abilities associated with pronounced morphological and biochemical changes have longer residuals.

The first factor relates to training duration before cessation; it also relates to the long-term adaptation process. Certainly, low and medium-class athletes have relatively low levels of motor abilities and can improve them faster, but they still do not amass sufficient levels of biochemical and morphological adaptation. Hence, they lose short-term training effects faster than more experienced athletes, who retain these training outcomes for longer.

The second factor relates to load concentration and is more relevant for qualified athletes whose training cycles entail highly concentrated workloads directed towards a limited number of motor abilities. Such a design provides more pronounced training stimuli and higher improvement rate (see Chapter 4). However, cessation of such a training program leads to the decline of previously developed abilities. Hence, training residuals after highly concentrated training are shorter than after complex training with a lower rate of motor ability development.

The third factor is also concerned with long-term adaptation. Aged and more experienced athletes are more accustomed to any kind of training stimuli;

consequently, their response is less pronounced and improvement rate is lower. However, the higher long-term adaptation level determines the slower rate of ability loss. As a result, more aged and experienced athletes have longer training residuals, which allow them to perform smaller training volume. This is consistent with the real sports world, where training volumes for elite aged athletes are 20-25% less than for their younger counterparts.

The fourth factor postulates that appropriate specialized workouts helps to-support a detrainable ability and prevent its quick decrease. This approach can be particularly important for training plans, which presuppose consecutive but not simultaneous development of many abilities, some of which decrease and others increase.

The fifth factor concerns the biological backgrounds of motor ability improvement. The rate of loss of training results differs significantly across motor abilities; some physiological systems retain increased levels of adaptation longer than others. The main reasons for this retention are the rate of morphological changes induced by training, the quantity of enzymes regulating biochemical reactions, and the availability of energy resources like glycogen, creatinphosphate, etc. (see Figure 2.6). Specifically, improved aerobic productivity is determined by an increase in capillary density, glycogen storage and particularly by the amount of aerobic enzymes, which increases in comparing with the non trained people up to 120% and even more. In contrast, increased anaerobic productivity is supported by relatively small increases of phosphocreatine storage of about 12-42%, peak lactate accumulation of 10-20% and anaerobic enzymes of 10-30 %. Consequently, aerobic ability, which is supported by pronounced morphological and biochemical changes, retains near to peak level in highly trained athletes for weeks (Mujika & Padilla, 2001). Anaerobic abilities, particularly maximal speed, are conditioned by relatively weak morphological and biochemical changes and retain near to peak level for shorter periods of time.

Similarly to aerobic abilities the maximal strength training produces relatively long residual. Indeed, peak maximal strength is provided by improved neuromuscular regulation and enlarged muscle mass. Both factors are retained for a long time and determine slow loss of maximal strength. Conversely, strength endurance drops much faster after training cessation (Figure 2.9). Particularly performance in relatively short-time strength exercises, which relies on lactic tolerance remain on sufficient level during the first two-three weeks and afterwards decline quickly.

Case study. Eight collegiate swimmers performed standard-paced 200-yard swims following one, two and four weeks of detraining. Average blood lactate increased during the first week from 4.2 to 6.3, during the second week to 6.9, and after four weeks of detraining to 9.7 mM. (Wilmore and Costill, 1993). The initial blood lactate value (4.2 mM) indicates that test was performed near to level of anaerobic threshold. Detraining caused reduction of swimming economy and pace-specific endurance. Thus, maintenance of the same velocity required increased involvement of the anaerobic metabolism and much higher lactate production.

The sophisticated changes are noted with regard to peak speed ability. On the one hand this ability is less improved by training and drops less during detraining; on the other hand the peak-level of maximal speed, typical for sprint events, is obtained by very delicate and highly precise neuro-muscular interactions, which are relatively unstable and can be maintained only by means of purposeful and intense training stimulation.

More detailed consideration of residual training effects related to Block Periodization appears in Chapter 4, where this concept has particular importance.

Summary

Training effects are the outcomes of athletes' systematic efforts. Their comprehension and interpretation are important for both planning and analyzing training. *Acute training effect* is produced by the execution of several exercises and reflects changes in body state that occur during the exercise. *Immediate training effect* is evoked by a single workout or/and by a single day of training; correspondingly, it summarizes changes of body state induced by these workloads. *Cumulative training effect* reflects changes in body state and level of motor/technical abilities resulting from a series of workouts. The *cumulative training effects* determine whether improvement in an athlete's performance occurs or not. These effects draw special attention from coaches and athletes particularly when performances are not sufficiently successful. The changes in an athlete's body state that characterize cumulative training effect can be analyzed by appropriate physiological indicators, and/or with the sport-specific fitness measures including performance gains. There are special cases in which training effect and performance gains occur not in the final phase of the training program but after some temporal delay necessary for morphological and physiological changes to occur. This process is called *delayed transformation* and this particular type of adaptation in athletes is called *delayed training effect.*

One type of the cumulative training effect relates to a situation when an athlete stops train a certain ability that then begins to decrease. However, for a given period the ability can remain near the acquired level. Retention of developed sport abilities after training cessation beyond a given time period is called *residual training effect* and changes in body state that are retained over a given period are called *training residuals*. There are different types of training residuals: long-term training residuals, which are induced by many years of training and remain for a number of years; medium-term training residuals, which remain for a number of months, and short-term training residuals, which reflect changes in body state caused by the preceding training (Table 2.10).

Implementation of these concepts in coaching practice is essential for the block periodization, which is intended to make athletic preparation more efficient and training effects more manageable and predictable.

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Chapter 3. The athletes' trainability.

Human talent as the notion includes many ingredients; one of them, particularly important for sport, that outstanding athletes respond to training loads and exercises better than less talented individuals. This feature to react positively to training is called the *trainability*. Strongly speaking the trainability can be characterized as an ability to improve the working potential of athlete by means of specially organized purposeful training. At least three aspects seem particularly important from the viewpoint of the athletes' preparation:

- Heredity related determinations of trainability;
- How trainability changes with progression of athletic level;
- Gender related determinations of athletic trainability.

Elucidation of above mentioned particularities is the purpose of this chapter.

3.1. Heredity related determinations of trainability.

In order to understand the nature of trainability, the possibilities and limitations of athletic training, the following questions should be answered:

- Does really heredity contributes to great sport successes?
- What are the genetic conditionings of main somatic and functional traits?
- In what extent the response to training stimuli (cumulative training effect) is genetically dependent?

The above questions belong mostly to the area of sports genetics, where the studies of heredity contribution to physical activity and athletic performance are reasonable extensive. The specific approaches of genetic investigations, which can be applied to sport area, are the twin studies, family investigations and experimental studies on trainability.

3.1.1. Outstanding sport families.

The family studies are not frequently used in genetic investigations: the somatic and physiological traits of parents and their offspring were evaluated (review Malina and Bouchard 1986, Bouchard et al. 1997) in different populations of Europe and North – America: their results displayed great differentiation, both in respect to type of relation and to population under study.

Unfortunately, the classic quantitative genetic methods have a lot of limitations, especially in case of analysis the outstanding sport families. The coaches and sport scientists noted however that parents of top-athletes are usually (both physically and functionally) in a higher degree developed than population and often experienced in high-performance sport, some of them achieved outstanding results. Table 3.1 presents some of so called "sport dynasties".

Certainly, each outstanding athlete (Olympic, world champion and medal winner) is unique. Occasional occurrence of two outstanding athletes in one family is negligible; each sample of such family can be analyzed as the case study. The collection of these cases is of great interest for understanding the nature of sport talent and importance of heredity related factors.

Table 3.1
Examples of the families of world, Olympic champions and medal winners
(Sources – Kamper, 1983; Shvarts, Khrushchov,1984, Matthews, 1997).

Parents, country	Sport, achievements	Children, country	Sport, achievements
Father – Casmir Gustav, Germany	Fencing. Two gold and two silver Olympic medals at 1906	Son – Casmir Erwin, Germany	Fencing. Two silver Olympic medals at 1928; two bronze Olympic medals at 1936
Father – Swahn Oskar Gomer, Sweden	Shutting. Olympic champion at 1908, 1912; Olympic silver medal at 1920	Son – Swahn Alfred., Sweden	Shutting. Olympic champion at 1908, 1912; Olympic silver medals at 1920 and 1924
Father – Gerevich Aladar, Hungary	Fencing. Olympic champion at 1932, 1936, 1948, 1952, 1956 and 1960	Son – Gerevich Pal, Hungary	Fencing. Olympics bronze medal at 1972
Mother – Szekeli Eva, Hungary	Swimming. Olympic champion 1952; silver Olympic medal at 1956	Daughter – Gyarmati Andrea, Hungary	Swimming. Silver and bronze Olympic medals at 1972, European champion and two silver medals at 1970
Father – Gyarmati Dezso, Hungary	Water polo. Olympic champion 1952, 1956, and 1964; silver Olympic medal at 1948; bronze Olympic medal at 1960		
Father – Tishtenko Anatoli, USSR	Kayaking. World champion at 1970, European Champion at 1971	Son – Tishtenko Anatoli, USSR, Russia	Kayaking. World champion at 1990, 1991, 1994 (three times).
Father – Hall Gary, USA	Swimming. Silver medal at Olympics 1968 and 1972, bronze medal at Olympics 1976	Son – Hall Gary, USA	Swimming. Two Gold medals (relays) and two silver medals at Olympics 1996: Olympic

			champion 2000 (1 individual event, twice – relay)
Father – Anissin Viacheslav, USSR	Ice hockey, European and World Champion at 1973, 1974, and 1975	Daughter – Anissina Marina, France	Figure skating. Olympic champion 2002; Olympic bronze medal at 1998; World champion 2000; silver medals 1998, 1999 and 2001; European champion at 2000 and 2002
Father – Bure Vladimir, USSR	Swimming. Silver and two bronze Olympic medals at 1972, bronze Olympic medal at 1968, European champion 1970	Son – Bure Pavel, Russia, USA	Ice hockey. Olympic silver medal at 1998; Olympic bronze medal at 2002; Awards: Maurice Richard –goals leader (2), NHL All-star team (6)
		Son – Bure Valery, Russia, USA	Ice hockey. Olympic silver medal at 1998; Olympic bronze medal at 2002; NHL All-star team (1)
Father – Montano Mario Aldo, Italy	Fencing: Olympic champion 1972; silver Olympic medal at 1976 and 1980	Son - Montano Aldo - Italy	Olympic champion and silver Olympic medal at 2004
Father – Janics Milan, Yugoslavia	Kayaking. World champion at 1978, 1979 and 1982; silver Olympic medal at 1984	Daughter – Janics Natasha, Hungary	Kayaking. World champion at 2002-2007; two-fold Olympic champion at 2004

Certainly, very often the family education of the great athletes' children was oriented from the early childhood to sport ambitions; it is than possible that their training conditions were more favorable than among the average population. This factor's influence can not be ignored. However, and this is doubtless, the outstanding parents had to be genetically predisposed to certain sport activity; these heredity related benefits were partly transmitted to offspring. Hence, probability to succeed in high-performance sport is much higher in children of champions. Sergijenko (2000) was of the opinion that the offspring of the outstanding athlete have 50% probability to inherit the excellent athletic abilities; this probability reaches 75% in the offspring of parents consisted of two outstanding athletes (the last case occurred once in our list – family of Andrea Gyarmati). Omitting doubtless about precision of this suggestion, showed above cases are very impressive, indeed.

3.1.2. Genetic determination of somatic and physical traits.

Quantitative estimation of the inheritance although is very sophisticated allows to continue consideration of the first question and to answer the second one.

The most widely used method to assess the heritability of several traits is the twin investigation. In general, the idea of twin method is based on the comparison of the resemblance of identical (monozygotic) twins to fraternal (dizygotic) twins. Because the monozygotic twins have identical heredity all differences in their capabilities attribute exclusively to influence of environment. Dizygotic twins share one-half of their genes, their heredity is different but environment conditions are usually identical. In this case any difference observed between them in a trait must be attributed to heredity. The quantitative estimate of heredity effect is *heritability*, which characterizes the degree of genetic determination of the several traits.

Despite the obvious difficulties the twin studies form extensive and very informative branch of sport science that presents the valuable knowledge related to heritability of morphological traits and fitness characteristics.

This is well known that different sports have certain specific demands to body build of the successful athletes. The genetic determination of the most important somatic traits was thoroughly investigated; the several findings of these studies are summarized below (Table 3.2.).

Somatotype understand as compilation of body linear, broad and fatness dimensions is under different genetic control: linearity – strong, breadths and muscle mass – medium, fat mass – weak. It caused that they meaning as indicators of sport predispositions is different. Important meaning as a predisposition to many sports has body height. Body breadths can be also important as a factor affecting suitability for certain disciplines, despite of theirs less heritability. Total body fat is in a small degree genetically controlled. Hence, the athlete's body build can be successfully corrected in training processes (excluding linear dimensions).

Table 3.2.
Approaching heritability of main somatic traits (based on Kovař 1980, Shvarts and Khrushtchov 1984; Szopa et al. 1985 and 1999; Bouchard et al. 1997)

Characteristic	General genetic control	Approaching level of heritability
Body's lengths: height, extremities, foot	strong	70%
Body's breadths: shoulders, thigh etc.	medium	50%
Total body fat	low	20 – 30%
Muscle mass	medium	40%

Total body fat, extremely important variable for many sports, that in minor degree is dependent on heredity. Hence, the athlete's body build with excessive fat mass can be successfully corrected while the major body proportions can be changed in low extent. Anyway, predisposition to certain sports, which affected by pronounced demands to body lengths, is strongly inherited since the linear body dimensions have the heritability of about 70%. This statement answers partly to the question on how heredity contributes to sport successes.

The similar studies have been conducted with regards to heritability of several motor fitness characteristics (Table 3.3).

Table 3.3.

Heritability of several motor abilities characteristics
(based on Kovař 1980; Mleczko 1992 ; Klissouras 1997; Bouchard et al. 1997 ; Szopa et al. 1999)

Characteristics	General genetic control	Approaching level of heritability
Alactic Anaerobic Power	strong	70-80%
Lactacid Anaerobic Power	medium	~ 50%
Peak blood lactate	high	~ 70%
Aerobic Power (V_{O2} max)	low-medium	~ 30%
Maximal isometric strength	low	20-30%
Strength endurance (resistance to acidity)	medium	40-50%
Reaction time	low	20-30%
Coordination of arm movement	medium	~ 40%
Space orientation	high	~ 60%
Balance	medium	~ 40%
Frequency of movements	medium	40-50%
Flexibility	medium	~ 40%

This table includes only main functional abilities, but most important in many kinds of sports. As we can see, they are in general under much less (than somatic traits) genetic control. These traits are than more trainable than majority of somatic ones. Its is worthy to emphasize, that in previous publications estimated values of heritability were much higher than in a new, methodologically more correct investigations.

The mostly relevant metabolic characteristics was maximum aerobic capacity (oxygen uptake). Its history can serve as a perfect example of the evolution of views of particular investigators: since very high estimation of heritability of this ability in former works (over 90%) to relative low and trainable (about 30%) in a new publications (review see Bouchard et al. 1997). Particularly high level of genetic determination was found regarding to anaerobic (especially alactic) power and peak of blood lactate: in consequence – explosive strength, speed abilities etc. are strongly genetically controlled. High stage of genetic contribution displayed the coordination abilities steering by highest floor of nervous system like space orientation, intelligence etc. The rest of functional abilities demonstrated medium or low heritability and at the same time – great trainability.

In the light of heritability of various somatic traits the general situation with the event – specific trainability is more understandable. For instance, the athletes who have relatively low inherited level of anaerobic productivity will be very limited in the sprint disciplines where these demands are pronounced. The similar situation exists in other sports demanding high level of maximal speed. The situation in strength, endurance disciplines and particularly in highly coordinative events is much more optimistic; the heredity-related limitations in those sports are not so hard.

3.1.3. Genetic determination of cumulative training effect.

It should be emphasized that the extent of inheritance is very different with regards to several motor abilities and functions. Moreover, heritability of certain motor ability and heritability of training response to develop this ability can be also different. Relations between heredity dependent ability and training response can be described by three following options:

- the motor ability is strongly heredity dependent, the effect of training for this ability is strongly heredity dependent as well; at this case the final state and performance of an athlete are decisively genetically determined;
- the motor ability is strongly heredity dependent, but the effect of training for this ability is slightly heredity dependent; at this case the final state and performance of an athlete are moderately genetically determined;
- both the motor ability and the effect of training for this ability are slightly heredity dependent; at this case the final state and performance of an athlete are very few dependent on heredity and the other factors (preparation, restoration etc.) are of primary importance.

There were several studies where heritability of the response to training was investigated. The single cases only pertained to relatively long-term training and their results can be considered as the cumulative training effects.

Case study
Two identical twins-sisters were engaged to determine maximal aerobic power on running treadmill and in swimming flume (Holmer & Astrand, 1972). Both sisters were the swimmers; one of them was at that time the member of National team, the second one stopped her high-performance carrier a few years before the study but had diversified fitness program as the physical education student. Despite the drastic differences of their swimming-specific level and aerobic power measured in swimming flume, the maximal aerobic power that was attained by both twins in running was on the same level. Hence, hard swimming training allowed the successful sister to join the National sport elite, but didn’t affect her maximal aerobic power, which remained on the previous level.

Table 3.4 summarizes data of several studies. Interestingly that heredity related responses to training are very event-specific: the training induced responses of maximal strength and maximal speed are independent (or slightly dependent) on the heredity, while the cumulative effect of training for anaerobic glycolitic endurance, and particularly for maximal aerobic power is largely dependent of genetic factors.

Table 3.4.
Heritability of cumulative effects followed the training of different modalities

Modality of training	Study design	Outcomes	Source
Strength training	10-week isokinetic strength training of five pairs of	The results suggest that the training effect was independent of the heredity	Thibault, Simoneau et al, 1986

	monozygotic twins		
Aerobic training	20-weeks of endurance training of 10 pairs of monozygotic twins	The changes of maximal aerobic power are of 75-80% heredity dependent; the anaerobic threshold response depends on heredity of about 50%.	Prud'homme et al.,1984
Anaerobic training	15-weeks of high-intensity intermittent training of 14 pairs of monozygotic twins	The response of alactic capacity assessed by 10 s test is heredity independent; the response of glycolitic endurance assessed by 90 s test is about 65% heredity dependent	Simoneau et al, 1986

Special remark should be done according to inheritance of motor learning and technical skills perfection. The extensive studies, which have been conducted in this area relate to elementary motor tasks and doesn't touch the athletic skills (see review of Bouchard et al., 1997). Nevertheless the results suggest that sensitivity to motor learning is quite variable between the age groups, sexes and among several tasks. In general, the acquisition and perfection of non-athletic and relatively simple motor skills is not dependent or slightly dependent on heredity. It is true to suppose that genetic determination of highly coordinative athletic skills is low or moderate.

In conclusion it should be emphasized that the top-athletes are individuals, who inherited several somatic and physiological benefits as well as the ability to well response to training. Combination of these two factors determines possibility of reaching master level in sport skills and can be treated as main predispositions of sports talent. However final result of sports training (technical and motor mastery) depends predominantly on his/her long – term preparation. This gives a lot of freedom for the coaches' creativity, which even allows compensating (although partly) the genetic limitations. In addition the life conditions should be mentioned as the relevant factor supporting trainability: nutrition, sufficient resting, biological restoring, normal conditions for professional activity, proper psychological climate and social conditions.

3.2. Trainability and performance level

It is commonly known that low qualified athletes improve their performance very fast even if they do not train as hard and systematically as their more experienced counterparts. Obviously, their response to training stimuli is more pronounced and therefore, their trainability is better. This corresponds to training related principles of adaptation, which were considered in a previous chapter (1.2). However, even among novices of the same age and similar preliminary preparation the training response is very different. These particular aspects of trainability are considered below.

3.2.1. Long-term trend of trainability.

Usually training volumes and performance gains in record sports (track and field, swimming, speed skating, cycling etc.) are well documented. Coaches know the volume of exercises performed over given period and the progress attained. The normal situation is that in which training workloads increase continually but improvement rate, unfortunately, decreases. This typical situation is shown for the preparation of young swimmers in the graph in Figure 3.1.

Insert Figure 3.1 about here

The above graph shows that during from ages 12-17 the annual training volume increased from 665 to 1950 km while rate of performance gain decreased from 6.2 to 1.8%. This natural reduction of improvement rate is determined by many factors but first and foremost by biological adaptation to active training stimuli. This general tendency can be schematically presented as a funnel (Figure 3.2). Low-qualified athletes are very sensitive to any kind of workloads because of high positive transfer of motor abilities from specific and non-specific exercises to competitive performance. In other words, the targeted area of many exercises is very large and they produce a pronounced positive effect. Highly qualified athletes are selectively sensitive to special workloads, which should correspond to the specific physiological and technical demands of certain sport (1.2.2). Only these types of exercises provide positive transfer of motor abilities and skills. Therefore, the targeted area of exercise repertory is relatively small and only carefully selected exercises can directly affect the targeted abilities. Thus, (1) the targeted abilities of elite athletes are less accessible to training stimuli than among less qualified athletes; and (2) the trainability of highly qualified athletes is respectively lower.

Insert Figure 3.2 about here

The main consequences of the above factors can be expressed as follows:

1) the quantity of exercises effectively influencing event-specific fitness declines as the athlete's qualification level increases (funnel effect);
2) the specificity level of developing exercises (adequateness to competitive event) should increase in tandem with the athlete's qualification level;
3) the rational preparation of high-performance athletes demands a focused search for new (or relatively new) event-specific exercises in order to obtain the desired training effect.

3.2.2. High and low responders.

Imagine that a number of similarly qualified athletes perform the same training program. After some period several of these athletes achieve remarkable fitness gains; their reaction to this training can be qualified as *high response*. Some members of the group attain medium improvement; they manifest a *medium response*. The remaining athletes exhibit small or negligible improvement; their training results evidence a *low response*. Following this qualification all athletes can be subdivided into three different groups:

- low responders,
- medium responders, and
- high responders (Figure 3.3.).

Insert Figure 3.3 about here

As we already know from section 3.1, elite athletes attain their performance level thanks to high trainability and definitely belong to the category of "high responders". However, according to the graph in Figure 3.3, high responders can be found even at the low qualification level. This diagnosis requires an evaluation of improvement rate of sport-specific abilities following appropriate training programs. Indeed, the outcomes of longitudinal investigations confirm the high predictability of data received from early stages preparation for the achievements of adult athletes (Bulgakova & Vorontsov, 1990; Vorontsov et al., 1999). Of course, individual improvement rates show wide deviations as determined by biological maturation, previous experience and social factors. Not all successful elite athletes were recognized at the early stages of their preparation, some were ignored by inattentive coaches and administrators. The problem of gifted athlete identification has still not been resolved for practical purposes (see section 7.4.3). Nevertheless, implementation of the concept of "high-low responders" differentiation may assist in finding a practical resolution.

3.3. Trainability and gender differentiation

The general tendency of contemporary high-performance sport is reduction of differences between athletic achievements of women and men. For instance, in period between 1985 and 2004 women improved world records in marathon running by 4%, while men's improvement was only 1.8% (Cheuvront et al., 2005). Of course, the social and cultural factors postponed development of female high-performance sport and nowadays its level is in striking contrast with historical past. Nevertheless many aspects of gender differences (GD) remain still unclear and disputable. Namely, trainability of female athletes with regards to various fitness components is of great importance and will be considered below.

3.3.1. Gender differences in maximal athletic performances

Much data exists comparing the maximal muscular efforts of men and women. The majority of these comparisons have been executed regarding untrained or not equally trained subjects. However, the outstanding achievements of elite athletes have drawn the attention of sport experts since early in the last century. Perhaps the pioneer of such studies was Nobel Prize winner A.V. Hill (1928), who plotted the world records of men and women in running disciplines on a graph and analyzed the marked differences. Nowadays the number of athletic disciplines where female athletes compete in the same conditions as the males has increased dramatically. Correspondingly, the possibility for making comparisons increased as well. Generally, analysis of running disciplines is of special interest because they embrace a very large range of durations, from very short (100 m) until extremely long (100 km). Hence we can examine the contribution of different metabolic recourses over the broad range of work duration (Figure 3.4).

Insert Figure 3.4 about here

The curve on the graph demonstrates a well-defined peak corresponding to the 5 km event, where the female-male difference equals 13.3%. The minimal values are for the shortest event (100 m – 7.1%) and for longest distance (100 km – 5.1%). It can be assumed that maximal GD in 5 km is predisposed by the largest GD in corresponding metabolic recourses. This assumption will be examined in the next section.

Let's observe and compare GD in disciplines demanding maximal and explosive strength. The events with identical performance conditions for men and women are the high, long and triple jumps in a track and field program, and the snatch, clean & jerk in weightlifting, specifically in category 69 kg in the male and female program. Consequently, one can compare GD in typical explosive strength (high, long and triple jumps) and very demonstrative maximal strength exercises (snatch, clean & jerk) – Figure 3.5.

Insert Figure 3.5 about here

Thus, the total rank of the GD in maximal athletic performances can be expressed as the following:

- maximal speed disciplines (100m run) – 7.1%
- anaerobic glycolitic endurance disciplines (400-1500m run) – 9.7-11.2%
- medium duration endurance disciplines (5-10 km run) – 11.6-13.2%
- long duration endurance disciplines (marathon – 100 km run) – 8.1-5.1%
- explosive strength disciplines (jumps) – 15.9-17.4%
- maximal strength disciplines (snatch, clean & jerk) – 22.6-30%.

Comparison of the above GD in various events reveals a much higher superiority of men over women in explosive and maximal strength exercises as compared with maximal speed and endurance disciplines. Apparently, the marked GD in top-level athletic performances is predisposed by gender specific physiological factors, which presumably determine the athletes trainability.

3.3.2. Gender differences in physiological determinants of motor fitness

Let's consider firstly the gender differences in major physiological factors affecting top-performance and trainability (Table 3.5).

Table 3.5.
The major physiological factors affecting top-performance and trainability (Issurin & Lustig, 2006).

Factor	Gender differences	Reasons	Source
Body composition	Females have in average 10% more relative body fat and consequently lesser relative muscle mass	Muscle hypertrophy in men is stimulated by sex hormones while women have higher sensitivity for receptors of lypolisys	Astrand et al., 2003
Muscles contractility	No difference in the maximal strength and contractile velocity per unit of CSA of muscles	CSA of female muscles is smaller but the men have no histochemical benefits in the fiber content	Trappe et al., 2003
Cardiac output	Men have higher cardiac output due to larger stroke volume	Men's heart has greater left ventricle dimensions and benefit in blood pumping	Pelliccia et al.,1996

Fatigue resistance	Women have a greater fatigue resistance at moderate and low muscular efforts and recover faster than men	Women have beneficial central cardiovascular adjustments, reduced rate of increase in heart rate; men require a greater rate of descending drive to maintain a similar effort	Clark et al, 2003; Hunter et al, 2004
Substrate utilization	Women have decreased glycogen utilization and increased fat oxidation during prolonged exercises	Glycogen depletion is stimulated by sex hormones; females have favorable fat metabolism	Friedlander et al., 1998; Tarnopolsky et al., 1995
Economy	No gender differences at exercises of similar relative intensities	Similar energy supply for activity at equal relative intensities expressed to body mass	Daniels & Daniels, 1992
Hormonal factor	The testosterone value in males is 10- to 20-fold greater than in women	Sexual dimorphism of endocrine system; i.e. testes function in men.	Medical Encyclopedia 2004

The data in Table 3.6 refute the wide spread opinion on total males superiority in functional capabilities for strenuous physical efforts. In fact, female athletes have the same muscle quality as males, more favorable fatigue resistance in exercises of low and moderate intensity, better fat utilization during prolonged exercise, and faster recovery. The male benefits are mostly predisposed by anthropometric factors and various consequences of higher concentration of the male sex hormone testosterone, i.e., anabolic effect affecting muscle hypertrophy, greater production and depletion of muscle glycogen, more pronounced hypertrophy of the left ventricle induced by training, etc. In light of the above, the GD in motor abilities and athletic performances can be easier understood and explained. Let’s continue this consideration with regards to GD in athletes’ motor abilities (Table 3.6).

The strength-related sexual differentiation in particular is a popular matter for discussion and investigation, and the reason of male-female difference is attributed primarily to the anabolic effect of testosterone.

Table 3.6.
Gender differences in the athletes’ motor abilities (Issurin & Lustig, 2006)

Motor ability	Gender differences	Reasons	Source
Strength	Maximal strength of trained females is less of 30-40%; normalizing the strength to muscle mass decreases the gap till 5%	Anabolic effect of testosterone determines larger muscle mass in men of about 35% more than in females.	Issurin & Sharobajko, 1985
Explosive strength	Men have remarkable advantages particularly in upper body exercises	Hypertrophy of fast twitch fibers is greater in males; no benefits in muscles contractility and neural output	Drinkwater, 1988
Maximal speed	Male and female athletes obtain the similar peak and mean power related to muscle mass of the lower body musculature	There are no difference in phosphagen stores and anaerobic alactic metabolism in men and women	Maud & Schultz,1986; Weber et al.,2006
Anaerobic glycolitic endurance (capacity)	Glycolitic capacity related to body mass is about 32% less in trained females than in males	Muscle glycogen depletion and production is strongly stimulated by testosterone level.	Kots, 1986 Brooks et al., 1996
Aerobic power	Aerobic power of trained females is 10-25% less than in males; this gap reduces till 10% while is related to lean body mass	Lower oxygen delivery in females due to lesser hemoglobin mass, lower cardiac output and stroke volume	Drinkwater, 1988; Astrand et al., 2003
Aerobic long-duration endurance	Men have relatively small advantage that reduces with the increase of work duration.	Men have beneficial oxygen delivery and glycogen metabolism, but women are superior in fatigue resistance and fat oxidation.	Drinkwater, 1988; Tarnopolsky et al., 1995
Flexibility	Superiority of females in total-body flexibility evaluated by many tests	High elasticity of tendons, ligaments and connective tissues; favorable bone structure of joints.	Kibler et al., 1989

Coordination	Since age 18 coordinative capabilities of women 10% better than in men	Females have beneficial spatial orientation and fine motor tasks; they have better balance due to lower center of gravity location.	Tittel, 1988

The usual explanation is that absolute values of maximal strength are much higher in males. It is worthy to note that hypertrophy of fast twitch fibers and, correspondingly their cross-sectional area (CSA), is much more pronounced in males as compared with females, namely the area of these twitch fibers is 40% larger in trained men compared to untrained men, while trained females have only 15% superiority over the untrained women (Drinkwater, 1988). Consequently, male athletes have a considerable advantage in explosive strength and power exercises. However, this superiority is not as striking as in maximal strength, because female muscles have similar contractile velocity as in males (Trappe et al., 2003). In both maximal and explosive strength the superiority of males diminishes and becomes relatively small after normalizing the strength indices to muscle mass.

The GD in maximal speed is conditioned by: neural factors, which give no benefits to either sex; muscles contractility, which is also similar in men and women; and metabolic factors, where superiority of males is conditioned by greater mass of musculature (Weber, Chia & Inbar, 2006). More pronounced hypertrophy of fast twitch fibers in males gives them the advantage, still not so striking, in maximal speed exercises.

Endurance in highly intensive glycolitic exercises has to be preferable in males than in females; blood lactate accumulation in trained males is substantially higher than in similarly trained females (Kots, 1986; Issurin et al., 2001). This GD is conditioned by relatively higher glycogen production and breakdown in men, which is stimulated by the higher testosterone concentration (Brooks et al., 1996). In addition, the greater activity of glycolitic enzymes in males determines their higher rate of glycolitic metabolism (Simoneau & Bouchard, 1989).

Aerobic power serves as worldwide used indicator of athletes' endurance. Male athletes have a distinctive superiority that is associated with larger muscle mass and beneficial oxygen delivery to the muscles. The latter is provided by higher oxygen-carrying capacity of the blood due to larger hemoglobin volume (Drinkwater, 1989), as well as the greater stroke volume and cardiac output. Indeed, the stroke volume, as the blood amount pumped per one contraction, is much less in females because of smaller cardiac size and lesser volume and mass of left ventricle (Pelliccia et al., 1996). Normalization of the maximal oxygen uptake to the lean body mass reduces GD, but it remains still substantial (Astrand et al., 2003; Drinkwater, 1988).

Aerobic endurance for long-duration events has relatively small GD, and this can be explained by women's superiority in fatigue resistance and fat oxidation; this benefit increases with the increase of the work duration. Still the men outperform the women even in the super-marathon 100 km, thanks to anthropometric benefits (longer legs and, consequently, strides) and beneficial oxygen delivery.

It is a common assumption that women have greater flexibility than men. The females' superiority was proved in an investigation of more than two thousands athletes participating in various sports using many tests; female athletes were found to be significantly more flexible in all measurements (Kibler et al., 1989).

Coordination is frequently considered as an area of female advantage. This differentiation is particularly remarkable within the age interval of 18 until 30 years (Tittel, 1986). Various analysts have noted the better spatial orientation, sense of rhythm, body balance, and fine motor coordination in female athletes. It was hypothesized that sex hormones may affect motor skills; nevertheless there is no evidence that motor learning outcome is different in men and women (Mittleman & Zacher, 2000).

The above consideration allows us to summarize the event-specific physiological determinants with regards to analyzing maximal athletic performance (Table 3.7).

Table 3.7.
The main physiological determinants of GD in various events and the extent of male superiority (+ moderate extent, ++ high extent, - females' superiority, no –no GD)- Issurin & Lustig, 2006.

Event	Events' duration	Main physiological determinants	Males' superiority
Running			
100 m	about 10s	Muscles contractility Maximal anaerobic alactic power	no +
400 m	43-48s	Glycolitic anaerobic power Maximal anaerobic alactic power Muscles contractility	++ + no
1500 m	3.5-4 min	Glycolitic anaerobic power Glycolitic anaerobic capacity Maximal aerobic power	++ ++ +
5 km	12.6-14.4 min	Maximal aerobic power Glycolitic anaerobic capacity	++ ++
10 km	26.3-29.5 min	Maximal aerobic power, Aerobic long-duration endurance Glycolitic anaerobic capacity	++ + ++
Marathon	2.1-2.3 hr	Aerobic long-duration endurance Fatigue resistance Running economy	+ - no
100 km	6.2-6.6 hr	Aerobic long-duration endurance Fatigue resistance Running economy	+ - no
Jumps [a]			
High	0.18[b]	Muscles contractility	no
Long	0.11-0.12[b]	Stretch-Shortening Cycle behavior	no
Triple	0.10-0.12 [b]	CSA of fast muscle fibers Relative mass of the muscles	++ ++
Weightlifting [a]			
Clean &	Clean –	Muscles contractility	no

Jerk	0.9-1.2[c] Jerk – 0.8-1.1[c]	CSA of fast muscle fibers Relative mass of the muscles	++ ++
Snatch	1.06-1.15[c]		

[a] – as the event duration is presented the time of force application (s)
[b -] takeoff duration; adopted from Zatsiorsky, 1995;
[b] – active phase ob the barbell lifting duration; registered by G. Hiskia during World Weightlifting Championships– personal communication

Of course, besides considering that outcomes of biomechanical and anthropometric factors strongly affect the consideration of GD, these factors have been especially analyzed by researchers (review of Cheuvront et al., 2005). Nevertheless, focusing on major physiological determinants, we can point out that minimal GD occur in disciplines where males' benefits are smaller (100m) or several females' benefits partly compensate other disadvantages (100 km). On the other hand the maximal GD is marked for the distance of 5 km, where both major metabolic contributors, i.e. aerobic power and glycolitic anaerobic capacity, enable this striking men's superiority.

A simple comparison of GD in running performances with jumps and weightlifting disciplines reveals impressive males' superiority in events requiring maximal and explosive strength. Still, the GD in jumps is lesser than in weightlifting exercises. The jumps demand a much shorter time of force application (takeoff duration); this movement pattern requires extremely fast muscular contraction and stretch-shortening muscle behavior (Komi, 1988), where males have no gender-specific benefits. In the weightlifting exercises the time of force application (duration of the active phase of the barbell lifting) is 6-8 times longer than in jumps. Consequently, the movement execution is relatively slower, and demands of maximal strength exertion are much more pronounced. The maximal GD are conditioned here by a much larger relative mass of the muscles, despite the similar body weight within category 69 kg and greater CSA of fast muscle fibers.

3.3.3. Gender differences in training response

The GD in the cumulative training effect has drawn much attention of researchers and coaches, particularly in strength training, where substantial differences are expected. This is commonplace, because in hormonal anabolic stimulation the male athletes have a distinct advantage (i.e. higher trainability) in the strength training directed to enlarge muscle mass. In fact, the identical high resistance training program performed by male and female athletes caused a considerable benefit of strength gain in both sexes, although the men attained lesser improvement (Wilmore & Costill, 1993).

It is worthy to note that strength increase in female athletes was not accompanied by a large gain in muscle bulk, and therefore this progression was mostly determined by the enhancement of neural mechanism of the muscular contraction. It can be noted that these findings were obtained in a study with low-qualified amateur athletes. Perhaps the training response of top-level athletes would be different. This supposition can be examined in the example of the following study.

Study

A group of elite female kayakers (n=10) participated in a strenuous fitness program to improve maximal strength during 19-weeks preparation (Issurin & Sharobajko, 1985). It was hypothesized that performance improvement of female kayakers, who competed in the Olympic 500m event lasting about two minutes, demands a higher strength level. Correspondingly, a large amount of high-resistance exercises was performed in three regular workouts per week, in addition to routine water exercises. The athletes' diet and use of nutritional supplements was fully controlled. The cumulative training effect was evaluated by measurements of the maximal force of selected muscle groups in kayak-specific body positions; average power in the 4-minute stroke simulation test on a kayak ergometer; and determination of muscle mass (Figure 3.6). The training program resulted in a remarkable gain of the muscle mass in this female group. It is interestingly that female athletes obtained a substantial gain of the muscle mass, maximal strength; and maximal strength related to muscle mass. This means that both mechanisms contributed to strength improvement: muscle hypertrophy and enhancement of neural regulation of muscular contraction. The average power of the 4-minute ergometer test increased to a lesser extent, and this was consistent with the main objectives of the training program. Therefore, the top-level female athlete can exploit both sources of maximal strength increase, and can respond to strength training more effectively than was previously assumed.

Insert Figure 3.6 about here

Thus, strength improvement with muscle hypertrophy is not monopoly of males. At least two arguments can be given to explain the marked effect of female adaptation to strength training; they concern the hormonal response and hormonal sensitivity of female athletes. Fahey et al. (1976) reported that intensive strength exercises induced a reduction of the testosterone level of 20% in male athletes; the similar load caused remarkable increase of the testosterone level in females. Later, Cumming et al. (1987) found a similar response in women who performed high resistance exercises. However, it should be noted that the effect of hormones is determined not only by their concentration, but also by receptors' affinity of the target organs. In female muscles the receptive affinity to anabolic hormones is two times higher than that of males (Kreig et al., 1980; Viru, 1995). Hence, a remarkable anabolic effect can be achieved in the female organism, thanks to (1) exercise-induced stimulation of the testosterone excretion, and (2) higher sensitivity of the targeted receptors to anabolic hormones. Presumably, this pathway for compensating a low concentration of anabolic hormones in female organism is formed in high-level athletes as a result of long-term adaptation.

The GD in training responses to maximal speed and explosive strength exercises are equivocal. On the one hand male athletes have the considerable benefit of greater hypertrophy of the fast twitch fibers (Drinkwater, 1988**),** hence the training response to power exercises become more pronounced; on the other hand there are no GD in muscle contractility and neural adaptation induced by speed training (O'Tool, 2000).

The training responses to highly-intensive training are to a certain extent gender-specific. In untrained persons such training induces similar gains. For instance, 8 weeks of strenuous interval training of untrained women and men follows a similar increase of maximal aerobic deficit in the range of 19-21% to pre-training level (Weber & Schneider, 2002). However, higher testosterone concentration in men affects their better glycogen sparing in the muscles (Brooks et al.,1996). Tarnopolsky et al. (1995) reported that appropriate manipulations with diet and training allow for an increase in the muscle glycogen concentration in men by 41%, while the glycolitic storage in women did not change. Consequently, the females' trainability for anaerobic glycolitic exercises is limited by lower glycolitic capacity.

Aerobic training is an area where women usually achieve great improvement. Despite their inferiority in oxygen delivery, trained female athletes increase their aerobic power by 10-30%, and this range is very similar to the males' data (Wilmore & Costill, 1993). The experience of many national teams in endurance sports evidences that females perform similar training volumes of aerobic exercises as their male counterparts. Moreover, they usually attain the same training effects of aerobic endurance training as the males. The following study gives an example of this similarity of endurance training response.

Case study. Nine women and 14 men, elite kayakers aged 19-29 yrs, were followed-up during three months of early season preparation. The training program was mostly devoted to developing aerobic abilities and sport-specific strength capability. The weekly schedule consisted of nine-ten workouts with total time expenses for training about 24-27 hours. The cumulative training effect was evaluated by an incremental stepwise test of 4×500m with measuring of blood lactate and average velocity in each stage, as well as determination of lactate anaerobic threshold (AnT) and maximal performance (MaxP). Both, male and female paddlers remarkably improved their aerobic abilities, i.e., velocity of AnT increased by 8.4 and 7.8% and velocity of MaxP by 4.5 and 4.1%, respectively (Figure 3.7). Thus, no gender-specific effects were marked (Issurin, Lustig, 2006).

Insert Figure 3.7 about here

The sex-related specificity of coordination has previously been considered (Table 3.6). There are very few objective data concerning GD in training response to movement coordination programs. The experience of top-athletes in highly coordinative sports such as gymnastics, figure skating, etc., gives evidence that males and females are similarly trainable for technical stunts. The common opinion is that female athletes better adapt to technical skills demanding high flexibility, balance and medium force application, while the males are superior in motor tasks demanding great force or power. The high-performance coaches noted that male athletes for more initiative in acquisition and mastering of new motor skills and tools; the females are more consistent and sensitive to technical details. In general, high-performance athletes are similarly trainable for highly coordinative exercises and technical skills, irrespective of gender.

Table 3.8.
Summary of gender specific trainability with regards to different motor abilities.

Motor abilities	Trainability differentiation
Maximal strength	Female and male athletes have equal potential to improve the neural mechanism of muscular contraction; men have an advantage of muscular hypertrophy, which can be partly compensated by the higher sensitivity of the female muscles to endogenous anabolic hormones
Maximal speed (alactic)	Male athletes have an advantage conditioned by more pronounced hypertrophy of the fast twitch fibers; there are no GD in neural adaptation to maximal speed and explosive exercises
Anaerobic glycolitic endurance	Male athletes have a beneficial potential to increase glycolitic capacity concerned with higher glycogen concentration that depends on the testosterone level
Aerobic endurance	Despite the inferiority in oxygen delivery, the female athletes respond to aerobic training (aerobic power and long-duration endurance) similar to their male counterparts
Coordination	The female and male athletes have similar improvement potential; the rate of technical skills perfection doesn't depend on sex factors
Flexibility	It can be suggested that women are more trainable for flexibility exercises than men due to morphological benefits of their musculosceletal system.

Despite the extensive sex related information on flexibility, there is a deficit of data concerned the training response. It can be suggested that the morphological benefits of women (more elastic tendons, ligaments and connective tissues; favorable geometry of joints) may affect their higher trainability in tasks demanding a greater extent of flexibility. On the other hand, the relatively high pre-training level of females can reduce their training response compared to the less flexible males. It can be speculated that women are usually more trainable for flexibility exercises than men.

The above-considered data allow positive conclusions to be drawn relative to the trainability of female athletes with regard to different motor abilities (Table 3.8).

Summary

Trainability as a general human trait is extremely important for coaching, training, and studying. Unfortunately, it has very often been underestimated or taken into account intuitively. This chapter clarifies and elucidates the essence and particularities of trainability with regard to three generalized factors: heredity, athletic level, and gender. The first is illustrated by the study of sport dynasties where data about eleven families of champions are presented. Heredity problems in sport touch upon a wide spectrum of biological determinants, which include somatic and physical traits, and training responses to developing programs for various motor abilities. More specifically, a predisposition to certain sports presupposes an optimal combination of somatic traits, where one group is strongly dependent on heredity (e.g., the body's lengths: height, extremities, etc.); another group is moderately dependent (e.g., body breadths: shoulders, thighs), and some traits are slightly dependent (e.g., body fat). Similarly, several training responses are highly predetermined genetically (maximal speed, anaerobic glycolitic power), and other ones are much less heredity-dependent and therefore more trainable (maximal strength, aerobic power, movement coordination, flexibility). Unlike many previous publications, this position is more optimistic about the trainability of the majority of sport-specific features.

The second statement claims that trainability varies with athletic progress. The general tendency is towards a reduction in trainability as athletic level increases. In other words, more qualified and experienced athletes are less sensitive to training stimuli than their younger, less qualified counterparts. Two practical consequences emerge from this: the quantity of effective exercises is reduced with the increase of athletic level (funnel effect); the level of event-specific adequateness in developing exercises should increase as the level of athletic mastery rises. Depending on the individual improvement rate of their sport-specific abilities, athletes can be differentiated as high-, medium-, and low- responders. Apparently, high-responders are persons capable of extraordinary trainability, and this distinctiveness is extremely important for the identification of gifted athletes.

The gender-specific particularities of trainability were reviewed with respect to maximal athletic performances, their physiological prerequisites, motor abilities, and cumulative effects of systematic training. Maximal GD were noted in athletic disciplines requiring maximal strength (22.6-30%); explosive strength (15.9-17.4%), and a combined manifestation of maximal aerobic ability and anaerobic glycolitic capacity (11.6-13.2%). Minimal GD are characteristic of maximal speed events (7.1%) and disciplines demanding long-duration aerobic endurance (8.1-5.1%). It should be emphasized that female athletes have several benefits: more favorable fatigue resistance in exercises of low and moderate intensity, better fat utilization during prolonged exercises, and faster recovery. Male benefits are mostly predisposed by anthropometric factors (size, body mass, and lengths of extremities and torso, etc.); oxygen delivery, and various consequences of higher concentration of male sex hormones (more pronounced muscle hypertrophy, greater production and depletion of muscle glycogen, higher glycolitic ability, etc.). Similarly, male benefits in motor fitness relate to maximal strength, aerobic power, anaerobic glycolitic endurance, and, to a lesser extent, to explosive strength and maximal speed. Female athletes are superior in flexibility and general coordination. Despite the inferiority of females in several motor abilities, they can achieve favorable training responses, very often similar to those attainable by males, using gender-specific mechanisms of adaptation to maximal strength, aerobic, and highly-coordinative workloads. Female athletes choose their own pathway of technical mastery; they are more consistent and sensitive to technical details and adapt better to technical skills demanding high flexibility, balance, and medium force application.

In addition, various life conditions should be mentioned as relevant factors supporting trainability: nutrition, sufficient rest, biological restoration, normal conditions for professional activity, proper psychological climate, and social support.

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Chapter 4. Block periodization concept vs. traditional theory.

Many generations of scientists, coaches and athletes have tried to build a training system that would yield the best performance results. Their efforts have focused on three general problems:

- How to design the rational training plan for a sufficiently long period?
- How to implement such a plan optimally?
- How to reach the most favorable combination of all athletic abilities exactly at the main competition?

All these problems belong to the ***training periodization***, which is described as the purposeful sequencing of different training units (long duration, medium duration and short-term training cycles and sessions) so that the athlete can attain the desired state and the planned results. Because training periodization contains many variables and depends on many influential circumstances, the ideal model can exist only in theory. Nevertheless, each year we take another step towards more conscious planning and more complete understanding of training as a whole.

This chapter summarizes the two most prevalent views of training periodization: (a) the traditional approach which has been predominant for a long time, (b) the block periodization design, which has come into widespread use among high-performance athletes during the last decade.

4.1. Traditional theory of periodization: basics and limitations

Training periodization was founded initially during the 1950s in the former USSR and was established as a scientific concept by Matveyev in 1964. This theory was disseminated in Eastern Europe (Ozolin,1970; Harre,1973) and later in Western countries (Dick, 1980; Martin, 1980; Bompa, 1984), and constituted a compulsory part of training planning in high-performance sport. In general, the periodization theory exploits the periodic changes in all human biological and social activities (see the principle of cyclical training designing – 1.4.). For a long while, the theory was accepted as the universal basis for training in any sport and for athletes of any level of competence. The first criticism and trends for reform appeared at early 1980s in elite sport as the experience of top coaches stood in contrast to the entrenched theories. New approaches proposed by creative coaches and scientists appeared. Extensive discussions by sports experts took place in the 1990s in East and West European sports magazines. Let us first examine the basics of classic theory and their limitations from the viewpoint of high-performance sport.

4.1.1. The scope of traditional theory

The cornerstones of periodization are formed by a hierarchical system of training units that are periodically repeated (Table 4.1). The upper level of the hierarchy belongs to the Olympic Quadrennial cycle, juxtaposed with the greatest events in sport world life. The next level of the hierarchy is represented by the macrocycles. A macrocycle usually lasts one year but can be shortened to half a year and even less (this flexibility in the annual cycle subdivision is irrelevant to the block periodization approach). The macrocycles are divided into training periods. The training periods fulfill a key function in traditional theory because they divide the macrocycle into two major parts: the first for more generalized and preliminary work (preparatory period); the second for more event-specific work and competitions (competition period). In addition, a third and shortest period is set aside for active recovery and rehabilitation. The next two levels of the hierarchy are reserved for the mesocycles (medium-size training cycles) and microcycles (small-size training cycles); the bottom part belongs to workouts and exercises, which are the building elements of the entire training system.

Table 4.1

Hierarchy and duration of the training units

Training units	Time duration	Mode of planning
Quadrennial (Olympic) cycle	Four years – period between Olympic Games	Long-term
Macrocycle, perhaps annual cycle	One year or several months	
Training period	Several months as a part of the macrocycle	Medium-term
Mesocycle	Several weeks	
Microcycle	One week or several days	Short-term
Workout or training session	Several hours (usually not more than three)	
Training exercise	Minutes (usually)	

The repertoire of periodic training units provides sufficient freedom for training design. Although external factors, such as competition calendars and seasonal changes, dictate culmination phases and restrictions in training, a coach can select the sequencing, content and duration of training cycles and define the particularities of each training mean and method.

A further consideration of the traditional approach points out the general characteristics of the above-mentioned periods and subdivides them into several stages. The training content of each stage should be concretized with regard to workload volume and intensity (Table 4.2).

Table 4.2

General characteristics of training periodization in the traditional approach (based on Matveyev, 1981; own modification)

Period	**Stage**	**Aims**	**Workload**
Preparatory	General preparatory	Enhancing the level of general motor abilities. Enlarging the repertory of various motor skills.	Relatively big volume and reduced intensity of main exercises; high variety of training means
	Special preparatory	Development of the special training level; enhancing more specialized motor and technical abilities	Load volume reaches maximum; intensity increases selectively
Competition	Competitive preparation	Enhancing event-specific motor fitness, technical and tactical skills; forming the individual patterns of	Stabilization and reduction of volume; increase of intensity in event-specific exercises

		competition top-performance	
	Immediate pre-competitive training	Accomplishing event-specific fitness and attaining readiness for main competition	Low volumes, high intensity; fullest modeling of forthcoming competition
Transitory	Transitory	Recovery	Active rest; use of variable pleasant activities

Initially the traditional approach presupposed one macrocycle a year; a typical design is presented in Figure 4.1.

Insert Figure 4.1 about here

The one-peak annual cycle was particularly suitable for seasonal sports (like skiing, skating, rowing etc.) but did not meet the demands of sports where athletes competed in any and all seasons (like fencing, swimming, ball games). Later modifications admitted two and three macrocycles within the annual cycle. Each macrocyle is subdivided into three periods, which are characterized by specific combinations of training aims and workloads (Figure 4.2).

Insert Figure 4.2 about here

The mesocycles, the medium sized training cycles, have been interpreted in different ways. Several authors offered eight sub-types of mesocycles, the other ones more. The students remember their titles until the exams and forget at once after them; the coaches didn't use these terms or utilize several "home-made" definitions. The Block Periodization Concept proposes much simplified mesocycles' classification; the coaches keep it in mind without excessive efforts (4.2.3).

The microcycles, as the shortest training cycles, elicit fewer contradictions. Despite the lack of unanimity among authors in regard to the names of the different microcycles, the following summary of many publications may help to make some order (Table 4.3.)

Table 4.3.

Microcycle types identified basing on summary of many publications

Name*	General characteristics
Adjustment, involving, initializing	Medium load level, gradual increase in workload
Loading, developmental, ordinary	Increased load level, use of big and substantial workloads

Impact, shock, microcycle of extreme load	Use and summation of extreme workloads
Pre-competitive, tuning, peaking	Medium load level, the use of event-specific means and drills
Competitive	Sport and event-specific performances
Restoration, regeneration	Low load level, use of the wide spectrum of restoration means

* The underlined title is the version preferred by the author

4.1.2. Merits and demerits of the traditional approach

The traditional theory of athletes' training was formulated at a time of very limited knowledge and scientifically proven guidelines for coaching. Traditional training periodization, which adopted up-to-date know-how of the 1960s, was a breakthrough for coaching and training science. Many of the elements postulated then remain valid to this day, including the hierarchical taxonomy and terminology of training cycles, differentiation between general and specific athletic preparation, seasonal trends of exercise volume and intensity, basic approaches to short-term, medium-term and long-term planning, etc. Of course, it would be unrealistic to expect that all of the ideas proposed more than four decades ago remain applicable today. Several of the principles of athlete preparation have no importance in the alternative Training Block approach.

> **Example**. The *principle of unity of general and specific preparation* was postulated in classic theory with regard to high-performance training emphasized the importance of event-specific means within long periods of generalized preparation, where this specificity could be ignored, and, conversely, the importance of general exercises during long competitive periods, when specific means are totally predominant. The *principle of continuity* was relevant when athletes lost motivation to train during long periods of monotonous training far from serious competitions. The principle of *wave-shape training design* was important to prevent the overloading so potentially prevalent during the prolonged periods of hard workloads typical of traditional planning.

The traditional design is appropriate for low- and medium-level athletes. However, it does not work well for high-level athletes. Traditional theory entails a number of contradictions, which dramatically reduce the effectiveness of preparation (Table 4.4.).

Table 4.4.

The main contradictions of the traditional training approach for high-level athletes (Issurin, 2007).

Factors	Contradictions	Consequences
Energy supply	Concurrent performance of	Energy is directed to many

	diversified workloads can not be provided by sufficient energy supply	targets while the main target doesn't get appropriate priority
Restoration of different physiological systems	Because of differing periods of recuperation in different physiological systems, athletes do not get sufficient restoration	Athletes suffer from fatigue accumulation and can't concentrate efforts on main targets
Compatibility of various workloads	Exercises of various modalities often interact negatively due to energy deficit, technical complexity and/or neuromuscular fatigue	Performance of certain loads eliminates or reduces the effect of previous or subsequent workouts
Mental concentration	Performance of stressed workloads demands high levels of mental concentration that can't be directed at many targets simultaneously	Mental concentration dissipates; a number of exercises are performed with reduced attention and motivation
Sufficiency of training stimuli for progress	The sport-specific progress of high-level athletes demands large amounts of training stimuli that can't be obtained by concurrent training for many targets	Complex simultaneous development of many abilities doesn't provide sufficient improvement for high-level athletes

For instance, preparatory period training for top-athletes in endurance, combat sports, ball games and aesthetic sports presupposes the development of general aerobic ability, muscle strength and strength endurance, improvement of general coordination and general explosive ability, basic mental and technical preparation, mastery of the tactical repertory, and treatment of previous injuries. Each of these targets requires specific physiological, morphological and psychological adaptation; many of these workloads are not compatible and cause conflicting responses

Study and example. The highly qualified male swimmers were followed up during eight weeks of the early season preparation. The athletes performed a strenuous fitness program combined with extensive swimming, which included resisted exercises and power drills directed to the development of swimming-specific strength. The total number of workouts was usually 9-11 per week The training outcomes were evaluated by strength estimates: maximal force of tethered swimming (F_{tsw}), dry-land explosive strength (F_{exp}), and dry-land strength endurance (***SE***). The fitness program resulted in a remarkable enhancement of strength endurance, while the swim-specific strength and explosive strength didn’t improve (Figure 4.3). During this entire period the swimmers improved their swimming preparedness, evaluated mostly by endurance tests. Therefore, the global aim of the fitness program was not obtained: although the swimmers enhanced their strength endurance, they did not improve their maximal swim-specific strength, and their explosive strength ability decreased. Although a substantial part of the fitness program included maximal and explosive strength drills (about 30% of the time expended for a dry-land program), the expected training effect was dramatically impaired by negative interaction of these workloads with the strength endurance routines and extensive swimming program (personal archive of author)

Insert Figure 4.3 about here

Indeed, the maximal strength progression requires muscles hypertrophy and enhancement of the neural mechanism of muscular contraction. The last one is of primary importance for improving of explosive strength ability. The extensive endurance workloads capture the metabolic energy that is necessary for anabolism during post-exercise recovery, and this suppressed the muscles' hypertrophy. On the other hand, enhancement of the neural mechanism is conditioned by the state of the central nervous system and the sensitivity of the neuro-motor pool (Klausen, 1990). The observations of coaches and athletes' self-reports evidence that the strenuous high volume training program caused permanent fatigue; eventually, the state of the central and peripheral neural factors is far from optimal level, which is favorable for the improvement of the mechanism of muscular contraction.

Similar conflicting situations were marked by many coaches, but not all of them assessed their critically. However the most prominent coaches decided a long ago that developmental programs for maximal and explosive strength and for strength endurance should be separate. The problem among high-level athletes is that their progress demands large highly-concentrated workloads, that can not be managed simultaneously for a large number of targets.

One additional drawback of the traditional theory is its inability to provide successful participation in many competitions. Indeed, even the three-peak annual cycle design does not satisfy the international sport trend towards competitions throughout the year. The multi-peak tendency that is in obvious contradiction with traditional planning is very characteristic of modern top-sport. Let's consider the above-mentioned multi-peak tendency in the example of the world-star track and field athletes.

Example. There are preparation's data of three world leading athletes: Marion Jones (USA), Sergei Bubka (Soviet Union, since 1991 Ukraine), and Stefka Kostadinova (Bulgaria) - Table 4.5. Each of these three athletes had pre-season and season preparation lasting about 300-320 days. As can be seen in the table, the time span when these athletes competed and reached the peak-achievements, and when they had relatively lower results varied between 135 – 265 days: This is obviously that this long time span can not be subdivided into traditional preparatory period and competition period. On the other hand, the basic abilities of these athletes (maximal strength, capacity of aerobic regeneration) should definitely be maintained on a sufficient level during the 5 to 8 month span. Therefore, the appropriate training cycles for basic abilities and recovery should be incorporated into the program. The traditional scholastic scheme doesn't allow a solution to this problem, and the inability to provide such a preparation design by means of traditional approach is obvious.

Table 4.5.

Multi-peak annual preparation of world-star track and field athletes (based on Suslov, 2001; own modification)

Athlete, disciplines, best achievements	Example	Number of peaks in season	Typical intervals between the peaks	Total time span for competing
Marion Jones; 100-200m running, long jump; 3-time Olympic Champion 2000; 5-time World Champion	Season 1998	10*	19-22 days	200 days
Sergei Bubka; pole vault; Olympic Champion 1988; 5-time World Champion; world record holder	Season 1991	7**	23-43 days	265 days
Stefka Kostadinova; high jump; Olympic Champion 1996; 2-time World Champion; world record holder	Season 1998	11***	14-25 days	Winter -20 days; spring and summer – 135 days

* There are eight peaks in running and two separate peaks in the long jump; all the peaks were on the level of her personal season best results;

** All the peaks were within 3% zone of the personal season best result; namely – 595-612 cm;

*** All the peaks were within 3% zone of the personal season best result; namely – 200-205 cm

The above marked disadvantage of traditional planning was noted by many coaches, who modified the annual chart and inserted relatively short-term training cycles with highly concentrated workloads to ensure multi-peak preparation. These were, in fact, the precursors of the alternative training periodization. A few decades ago high-level coaches could be heard lamenting: We build up massive foundations of basic abilities, but when we complete the tower of specific fitness, the foundations are mired in a bog. This gloomy outlook reflected the practical observation that prolonged development of basic abilities doesn't guarantee the maintenance of these abilities at the high level that was achieved over time (the phenomenon of training residuals was conceptualized later, see 2.6.). Unfavorable seasonal trends in physiological and sport-specific variables were noted and commented upon in many follow-up studies of the preparation of high-level athletes; the pattern of these typical changes is presented in Figure 4.4.

Study and example. The group of highly qualified kayakers was followed up during their yearly preparation designed following classic theory. The incremental stepwise test was utilized to determine velocity of Anaerobic Threshold ((V-AT) and mean distance velocity in all-out performance (Vd). Peak Force on the paddle (PF) and Stroke Rate (SR) were obtained with the help of portable telemetry system. The anthropometric measurements allowed to calculate muscle mass (MM). As can be seen in Fig.4.3, the long period of general preparation (preparatory period) caused a substantial increase of aerobic endurance (V-AT), muscle mass and strength ability (peak force on the paddle). During the relatively long period of highly specialized competitive period, extensive aerobic workloads were replaced by more intensive event-specific exercises, maximal strength exercises affecting anabolism were reduced and even rejected as a harmful for racing technique. As a result, the velocity of Anaerobic Threshold and peak force decreased during the competitive period, and muscle mass diminished prior to competition. It is worth noting that mean distance velocity reached maximum for the targeted competition; this progression was obtained by means of increased stroke rate despite reduced force application to the paddle. It is obvious that the timing pattern for developing different abilities was far from optimal (Issurin et al., 1986).

Insert Figure 4.4 about here

4.1.3. Why the traditional planning approach should be revised

As can be inferred from this description, the drawbacks of the traditional training concept were a crucial factor in seeking an alternative approach. These limitations included:

- restrictions created by the simultaneous development of a number of motor and technical abilities;
- the inability to provide multi-peak preparation, i.e. successful participation in many competitions;
- limitations imposed by excessively prolonged periods of basic and sport-specific preparation.

Moreover, the tremendous changes in world sport over recent decades had a strong influence on the evolution of the training process. While the variety and uniqueness of each sport makes it difficult to be specific, these changes can be summarized in general as:

- a drastic increase in the number of competitions and competitive performances;
- a remarkable reduction in the total volume of training workloads;
- the appearance of new concepts affecting the planning and designing of alternative training periodization.

Increase in the number of competitions

An evident tendency in contemporary sport is participation in competitions through the whole season (Table 4.5) and a remarkable increase in competition days throughout the year (Figure 4.5).

Insert Figure 4.5 about here

At least three factors have determined the trend in competition activity:

- **Increase in the number of competitions** in international and national tournament programs: in the last two decades, international sport federations have initiated and supported the organization of traditional series of grand prix, world and continental cups, memorial trophies etc., which have become popular among top athletes and the sport media; similarly, national federations have built extensive competition schedules intended to engage a larger population of sub-elite athletes in ambitious preparatory programs;
- **Financial motivation of top athletes** has increased substantially: the premiums potential prize-winners can receive became obvious stimuli to reach peak-performance levels more frequently than proposed in the traditional periodization chart. At the same time, second echelon athletes have also modified their competition strategy to imitate the top athletes' patterns;
- **The contribution of competitions** to training stimuli has increased dramatically; more frequent competitions break routine training and change the relation between loading and recovery; advanced coaches exploited more frequent competitions to intensify the athlete's preparation.

Reduction in total volume of training workloads

This factor refers to the considerable reduction in total volume of training workloads among high-performance athletes. Figure 4.6 illustrates this tendency for representatives of different sports from different countries. A number of circumstances can be cited for this global trend:

Insert Figure 4.6 about here

Remarkable progress in training methods and sport technologies. Up-to-date knowledge of long-, medium-, and short-term training effects makes it possible to design training programs that prevent excessive workloads, which were often the result of insufficient understanding or critical appraisal. Monitoring technologies for heart rate, blood lactate, movement rate and technique have been incorporated into training routines so that acute and immediate training effects are now much more measurable and predictable. In particular, the modern approach to training planning has made it possible to replace the slogan "more miles make champions" to "knowledge gives power". This factor closely interacts with the next one.

Worldwide sharing of successful experiences among coaches. It is obvious that the modern world of elite-sport has become more open and dynamic. International training centers host athletes from different countries for training camps and extended preparation. Coaches' clinics, seminars and courses engage experts of world renown, who don't hesitate to lay out – for all to see and hear – items that were once classified as "top secret". Many successful coaches from countries that regulated experience-sharing by means of strictly enforced sport policy have taken the world as their stage. These are coaches possessing long-term experience in the use of extreme and sub-extreme training workloads, from the time when general training volumes were strictly prescribed. They knew that a substantial part of these excessive workloads was not useful, if not harmful, and now they share this knowledge with colleagues from many countries.

Increases in the number of competitions and starts. The excessive training loads were partly superseded by more pronounced competitive activity.

Rejection of illegal pharmacological programs. It is no secret that some illegal pharmacological interventions facilitated certain athletes' physiological responses, such as muscular hypertrophy and speedy recovery, and affected performance at higher workloads. Doping control – before, during and after competitions – initiated by the International Olympic Committee in the mid 1990s has become an indispensable part of modern sport and has helped to prevent the use and sharing of these harmful technologies in high-performance sport. One concomitant result was to reduce the capacity to maintain high-load training programs.

Social and political changes in post-communist countries. It is common knowledge that the highest workload volumes were performed by athletes of former communist countries where athletic preparation was strictly centralized. Integrative parameters of the training process (such as total mileage, total time expended on training, etc.) were imposed on national teams in the form of planning directives. Very often these directives proposed excessive training workloads as a tool to obtain more successful athletic performances. The social and political changes that these countries underwent were followed by the democratization of elite-sport, a reduction in administrative pressure and liberation of the coaches allowing them to display individual initiative. On the other hand, the economical upheavals engendered by the political changes in these countries exhausted most of the financial resources available to top sport. As a consequence, total workload volumes were substantially reduced. In a rippling effect, this change influenced training volume trends in other countries and caused load reductions there as well.

All of these circumstances and factors contributed to the search for alternative training approaches, which were offered by creative coaches and scientists with a practical orientation. Not every attempt to reform the traditional system was successful; however, revision tendencies gradually became stronger and more desirable for preparing high-performance athletes in the new conditions of markedly more competitions, a highly developed sport industry and a more open sport society that demanded a revamping of the training system. As a result several new concepts were implemented in practice and created the foundations for alternative periodization and advanced training theory.

4.2. The Block Periodization Concept - general outline

4.2.1. New concepts affecting the rationalization and designing of alternative training periodization.

In the 1980s, the concept that emerged among prominent coaches pertained to what is called *training blocks*. This idea was not conceptualized scientifically and was open to different interpretations; however, in its most comprehensive connotation, *training block* referred to a training cycle of highly concentrated specialized workloads. This definition corresponds to the common understanding of *the block* as an autonomous compact unit of several elements amalgamated for a specific function. Further consideration of training blocks as a coaching concept leads to several logical consequences:

- Highly concentrated training workloads cannot be managed for many targets at the same time and therefore, this is an alternative to the then widespread practice of simultaneous complex development of many abilities;
- Athletic performance in any sport usually demands the mastery of many abilities, which, in the case of training blocks, can be developed only consecutively but not concurrently;
- Developing a process that includes morphological, organic and biochemical changes requires a sufficiently long time period of about 2-6 weeks, which corresponds to the duration of the mesocycles; hence, training blocks are mostly *mesocycle-blocks.*

One of the most successful coaches to achieve magnificent results using this alternative training system was Anatoly Bondarchuk, who coached the gold-, silver-, and bronze-medal winners in the hammer throw at the 1988 Olympic Games. Thus, he fulfilled the nearly unattainable dream of having a whole Olympic podium occupied by the athletes of the same coach. Basing his approach on his own personal athletic experience (he was Olympic hammer throw champion in 1972) and careful investigation of throwers' training design (as part of his doctoral studies in 1988), Bondarchuk created the original periodization chart that completely reformed the traditional approaches to training planning (Bondarchuk, 1986 and 1988). Dr. Bondarchuk established three types of properly specialized mesocycle-blocks: developmental, where workload levels gradually increase to maximum; competitive, where the load level is stabilized and athletes are focused on competitive performance; and restoration, where athletes utilize active recovery and prepare for the next developmental program. The duration of the two first types of mesocycles is usually four weeks while the third type can be shortened to two weeks. The sequencing of these blocks depends on the competition schedule and on the responses of individual athletes. The outstanding characteristic of the training program design is alternation and repetition of the exercise repertory in each mesocycle-block (every four weeks). The terms of traditional periodization like "preparatory, competitive and transitory periods" were used, but the author noted that in his own concept their essence is radically changed.

As already mentioned, the "winds of reformation" became stronger in the earlier 1980s. At that time elite USSR canoe-kayak paddlers performed enormous annual volumes of exercise; the prevailing opinion was that this load level was excessive and that the training design could be made more rational. The idea of training block- and mesocycle- sequencing was conceptualized, implemented and proved in practice, and then published (Issurin & Kaverin, 1985). Three types of mesocycle-blocks were elucidated: accumulation, which was devoted to developing basic abilities such as general aerobic endurance, muscle strength, and general patterns of movement techniques; transformation, which focused on developing more specific abilities like combined aerobic-anaerobic or anaerobic endurance, specialized muscle endurance, and proper event-specific technique; and realization, which was designed as a pre-competitive training phase and focused mainly on exercises for race modeling, obtaining maximal speed and recovery prior to the forthcoming competition.

Mesocycle duration was established according to physiological and biochemical prerequisites and usually allowed four weeks for accumulation and transformation mesocycles, and two weeks for realization. These three mesocycles were combined into a separate training stage, which ended with competition; a number of training stages formed the annual macrocycle, which was formally subdivided into preparatory and competition periods, but this differentiation was of minor importance.

The modified training design allowed an average 10-15% reduction in annual training volumes. Follow-up measurements of the national team during preparation indicated enduring and considerable improvement of the main fitness components in all subgroups. The radically reformed preparation programs resulted in outstanding performances in the 1988 Seoul Olympic Games (three gold and three silver medals) and in the World Championships of 1989 and 1990 where eight and nine gold medals, respectively, were won.

One more concept affecting elucidation and implementation of the alternative preparation approach is residual training effect (see 2.5), a term first coined by Brian and James Counsilman (1991). Compared to other types of training effects (acute, immediate, cumulative and delayed), residual effect remains relatively new and obscure. The residual training effect, as has been indicated earlier (Table 2.1), refers to *the retention of changes induced by systematic workloads beyond a certain time period after the cessation of training*.

The phenomenology of residual training effect is closely connected with the process of detraining, which was previously understood as a loss of "trainedness" when training is stopped. In fact, detraining in high-performance sport may occur selectively according to specific abilities when they are not stimulated by sufficient training. For instance, maximum oxygen uptake among highly trained endurance athletes decreases when total weekly volume is reduced below a certain level (Steinacker, 1993; Steinacker et al., 1998). Similarly, large volumes of highly intensive exercise do not prevent detraining and loss of aerobic endurance during the taper (Mujika, 1999). When training is designed in the traditional manner and many abilities are developed simultaneously, the risk of detraining is negligible because each target (certain motor or technical ability) receives some portion of the stimuli. However, if these abilities are developed consecutively, as proposed above (Issurin & Kaverin, 1985: Bondarchuk, 1986, 1988), the problem of detraining becomes very important. Indeed, if you develop one ability and lose another one at the same time; you have to take into account the duration of the positive effect of a given type of training after its cessation and how fast you will lose the obtained ability level when you stop training it. In other words, you have to know the residual effect of each type of training. A recent study presents data summarizing the characteristics of the duration of training residual with regard to different motor abilities (Table 4.6.)

Table 4.6.

The duration and physiological background of the residual training effects for different motor abilities after a cessation of developing program (Issurin & Lustig, 2004)

Motor ability	Residual duration, days	Physiological background
Aerobic endurance	30 ± 5	Increased amount of aerobic enzymes, mitochondria number, muscle capillaries, hemoglobin capacity, glycogen storage, higher rate of fat metabolism
Maximal strength	30 ± 5	Improvement of neural mechanism, muscle hypertrophy mainly due to muscle fiber enlargement
Anaerobic glycolitic endurance	18 ± 4	Increased amount of anaerobic enzymes, buffering capacity and glycogen storage, higher possibility of lactate accumulation
Strength endurance	15 ± 5	Muscle hypertrophy mainly in slow-twitch fibers, improved aerobic/anaerobic enzymes, better local blood circulation and lactic tolerance
Maximal speed (alactic)	5 ± 3	Improved neuro-muscular interactions and motor control, increased phosphocreatine storage

The rates of loss of training effects and respective training residuals vary widely for different motor abilities. Some physiological systems retain increased levels of adaptation longer than others. For example, improved aerobic capacity is determined by pronounced morphological and biochemical changes, i.e., increase of capillary density, glycogen storage and particularly the amount of aerobic enzymes, which increases by 40-90% (see Figure 2.6). This is in contrast to the much lesser local adaptations seen in athletes after sprint training: increases of phosphocreatine storage (2-5%), peak lactate accumulation (10-20%) and anaerobic enzymes (2-20 %). Consequently, aerobic ability, which is supported by pronounced morphological and biochemical changes, is retained for a number of weeks at near-peak level; while anaerobic abilities, particularly maximal sprint, retain near-peak levels for much shorter periods (Table 4.6).

Maximal strength gain in top-level athletes is determined by pronounced morphological, biochemical and neural changes, such as enlargement of the cross-sectional area of muscle fibers, increased number of fibers (hyperplasia), recruitment of previously inactive motor units and synchronization of their activity, and increased discharge frequency of moto-neurons (Zatsiorsky, 1995). All these significant adaptations create a relatively long training residual for strength training.

Training residuals of strength endurance are dependent on performance duration and the degree of mobilization of anaerobic resources; strength endurance for long-duration performance has relatively longer residuals, thanks to pronounced aerobic adaptation.

The changes induced by training for peak speed ability, as it was already discussed above, are characterized by fewer gains and shorter residuals. Highly concentrated sprint training causes relatively small increases of quickly available energy sources such as ATP and phosphocreatine, and enzymes such as creatine kinase (Thorstensson, 1988). In addition, peak speed ability is based on very delicate and highly precise neuro-muscular interactions, which are relatively unstable and cannot be maintained at the highest level without specially organized training.

This knowledge about training residuals and the time course of detraining is important when the planning concept turns from simultaneous to consecutive development of sport-specific fitness components. Indeed, when we stop developing a specific ability we should be able to predict how long this ability will remain at the "sufficient" level. This information should determine the appropriate sequencing and timing of the training cycles.

4.2.2. General principles of the Block Periodization Concept

The revised approach, called the Block Periodization Concept (BPC) has been developed and concretized in general principles and guidelines for alternative training systems.

General principles of the revamped training system reflect the essence of the concept; their unity and subordination are displayed in Figure 4.7.

Insert Figure 4.7 about here

Concentration of training workloads is the most decisive and fundamental principle of the BCC. The rationale, which mediates it, is the long-known fact that only highly concentrated training workloads can produce sufficient stimulus for remarkable gain of a given motor and/or technical ability in high-level athletes. This is the cornerstone principle from which the following emerge: highly concentrated training demands minimize the number of abilities that can be affected simultaneously (the alternative is a complex design where many abilities are developed simultaneously); consecutive development is the only possible approach when the number of sport-specific decisive abilities is more than the number of abilities that can be trained simultaneously (the alternative complex approach has no hard limitation in this item, where one meso- and microcycle combines the workloads for many abilities); finally, the mesocycle-blocks should be specialized and compiled in order to produce one of three different effects: *accumulation* (athletes accumulate the potential of basic motor and technical abilities); *transmutation* (athletes transmute their motor potential to event-specific preparedness); and *realization* (athletes realize their preparedness as readiness for competition and attain the planned result). Therefore, the medium size training cycles, called mesocycle-blocks, are the most prominent embodiment of the general idea of the Block Periodization Concept: they are much more concentrated, more specialized, and more manageable in whole training programs.

4.2.3. Compiling the annual cycle

As in the traditional approach, annual cycle planning begins by determining the target-competitions, which are usually scheduled by international and national sport authorities. The specific moment when the revised training approach becomes apparent is in the subdivision of the whole annual cycle into a number of training stages, each of which contains mesocycles of three types: accumulation, transmutation and realization (Table 4.7).

Table 4.7

The main characteristics of the three types of mesocycle-blocks (Issurin, 2007).

Main characteristics		**Mesocycle type**	
	Accumulation	**Transmutation**	**Realization**
Targeted motor and technical abilities	Basic abilities: aerobic endurance, muscular strength, basic coordination	Sport-specific abilities: special endurance, strength endurance, proper technique…	Integrative preparedness: modeled performance, maximal speed, event specific tactics
Volume-intensity	High volume, reduced intensity	Reduced volume, increased intensity	Low-medium volume, high intensity
Fatigue-restoration	Reasonable restoration to provide morphological adaptation	No possibility to provide full restoration, fatigue accumulated	Full restoration, athletes should be well rested
Follow-up particularities	Monitoring the level of basic abilities	Monitoring the level of sport-specific abilities	Monitoring maximal speed, event specific strategy etc.

The rational sequencing of the mesocycles within the training stage makes it possible to obtain optimal superimposition of residual training effects as displayed in Figure 4.8. The diagram shows principal options for obtaining optimal interaction of training residuals, so as to allow competitive performance at a high level for all motor and technical abilities. This possibility is based on the fact that training residuals of basic abilities last much longer than residuals of more specific abilities, while residuals of maximal speed and event-specific readiness are the shortest (Table 4.6).

Insert Figure 4.8 about here

Referring to the above diagram, it can be seen that the duration of the training stage is determined by the length of training residuals and should be about two months. In actual fact, the training stages can be shorter (near to peak season, for instance) or longer (at the season's beginning or to meet specific needs). In the second case (longer training stages), special measures can be used to prolong residual training effects (see short-term planning). It is worth noting that each training stage gives the appearance of an annual cycle in miniature: it includes a training block resembling the preparatory period (accumulation), a training block resembling the competition period (transmutation), which is ending by tapering (realization) and competition performance. Based on the above, the annual cycle design can be viewed as a sequence of more or less autonomous stages, where similar aims are obtained by means of a partially renewed and qualitatively improved training program. A test battery repeated at each stage together with competitive performance results will help to monitor the training process and provide feedback that can be used for ongoing evaluation and program rectification.

Finally, the number of training stages in an annual cycle depends on the particularities of a given sport, its calendar of important competitions, etc., and usually varies from four to seven. The typical annual cycle following the Block Periodization Concept is shown in Figure 4.9.

Practical implementation of the BPC facilitates a number of benefits as compared with the traditional model:

- Total volume of exercise: the Block Periodization model allows a reduction in total mileage and time expended on training without substantially changing the total number of workouts;
- Monitoring of trainedness is more purposeful and effective; reduced number of targeted abilities requires appropriate tests; "dose-effect" analysis can be easily performed with respect to different training stages;
- Psychological particularities are more beneficial: the athletes can focus on a reduced number of targets, consequently allowing more effective maintenance of mental concentration and motivation level;
- Nutritional aspects can be more carefully taken into account; a high protein diet can be offered to enhance the anabolic effect of strength training; carbohydrates are particularly important in mesocycles for special and strength endurance.

Insert Figure 4.9 about here

4.3. The main consequences of the modern approach

Table 4.8 summarizes the most relevant differences that emerge from a comparison of the traditional and non-traditional approaches to training periodization and annual chart designing. The dominant principle focuses on a total strategy of compiling training workloads, where the use of highly concentrated workloads contrasts with the complex administration of various workloads in the traditional approach. The residual training effect concept constitutes part of the scientific background for the new approach but plays no part in the background of the classic theory, which was based exclusively on the cumulative training effect. Similarly, temporal sequencing in the development of a wide range of abilities entailed mainly simultaneous training in the classic approach and strictly consecutive development in the block-structure. The term “periodization” itself reflects the most meaningful planning component of the classic approach – preparation periods. As mentioned earlier, the most meaningful planning component in the alternative approach is the training stage that consisted of three sequencing mesocycle-blocks. Unlike the traditional model, the BPC allows for successful implementation of a multi-peak annual plan; the intermediate peaks can be planned for mid-season and even for the early part of the season. The general physiological mechanism of adaptation is very different when the two approaches are compared: the traditional model exploits mainly adaptation to concurrent training stimuli affecting many abilities while the non-traditional model presupposes superimposition of residual training effects induced by highly concentrated training stimuli administered consecutively.

Table 4.8.

Principal differences of training design based on the classic approach and BPC (Issurin, 2007).

Characteristics of the training design	**Traditional model**	**Block Periodization model**
The dominant principle of workload compilation	The complex use of different workloads directed at many abilities	The use of highly concentrated workloads directed at a minimum of targeted abilities
Scientific background of the planning approach	Cumulative training effects	Cumulative and residual training effects
Temporal sequencing in developing different targeted abilities	Predominantly simultaneous	Predominantly consecutive
The main meaningful planning component	Period of preparation: preparatory, competitive and transitory	Stage of preparation that includes and combines three types of mesocycle-blocks
Participation in competitions	Predominantly in the competitive period	Predominantly at the end of each stage
General physiological mechanism	Adaptation to concurrent training stimuli affecting many different targets	Superimposition of residual training effects induced by highly concentrated training stimuli

Summary

The traditional theory of training periodization was developed as a universal approach to planning and preparation analysis. The tremendous changes in high-performance sport as well as the dissemination of new training technologies led to the evolution of general theoretical positions and the appearance of several non-traditional coaching concepts. The alternative to the traditional theory preparation approach called the "Training Block Periodization" reflects the successful experience of many prominent coaches and the results of long-term studies conducted on top-level athletes. The general idea of the alternative approach presupposes the use and sequencing of specialized mesocycle-blocks, where highly concentrated training workloads are focused on a minimal number of motor and technical abilities. Unlike the traditional theory of training periodization that postulates simultaneous development of many abilities, the alternative concept offers consecutive development of the targeted abilities in successive mesocycle-blocks. The rational sequencing of these blocks is based on residual training effects, i.e., the retention of changes induced by certain training beyond its cessation. These training residuals are of special importance when athletes improve their abilities consecutively and not concurrently as in the traditional model.

The Block Periodization Concept proposes and utilizes an original taxonomy of mesocycles that consists of three types of specialized blocks: *accumulation,* for developing basic motor and technical abilities (mostly aerobic and muscle strength abilities as well as basic technical skill); *transmutation,* for developing event-specific abilities (mostly anaerobic or/and aerobic-anaerobic abilities, and more specialized technical skills), and *realization*, for maximal speed, event-specific tactics and full restoration prior the forthcoming trial or competition (this block is very similar to the widely-known concept of pre-event tapering). These three mesocycle-blocks taken as a whole form the training stage, that is, the most meaningful component of alternative training periodization. This contrasts to classic theory where the most meaningful component is the training period.

It should be noted that the traditional approach has visible benefits for the preparation of low- and mid-level athletes. The complex administration of workloads directed at many abilities makes training more diversified, attractive and lively. The improvement of relatively lower athletic abilities doesn't require highly concentrated training workloads, because medium-level concentration still provides sufficient stimulation. The opposite situation is typical for high-performance athletes who need high concentrations of appropriate exercises in order to progress. Table 4.8 presents the main differences between the traditional and alternative training models. The benefits of the Blocks Periodization Concept as compared with the traditional model are the following: (1) total volume of training exercise can be remarkably reduced, hence reducing the incidence of overtraining as well; (2) the multi-peak training design allows and facilitates successful participation in many competitions over the whole season; (3) monitoring can be more efficient because of the substantial reduction in the number of athletic abilities to be evaluated within each mesocycle; (4) diet and restoration program can be appropriately modified according to the predominant type of training and, finally, (5) a multi-stage annual plan creates more favorable conditions for peaking in time for the main competition of the season.

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Chapter 5. Workout: general positions and compilation guidelines

Workouts are the minimal complete structural components of a training system, which when joined and sequenced form all other larger training cycles and stages. The current situation with regard to training workouts is rather contradictory. On the one hand coaches and athletes know how to compile single workouts in their own sport. On the other hand, as we have seen in previous chapters, training approaches and preparation systems are constantly changing and improving. Eventually, training workouts are modified as well. Some coaches reach a level of mastery in their creations, but frequently they can not (or do not want to) explain how they compiled the aggregate of these amazing sessions. The aim of this chapter is to present the most relevant general approaches to workout compilation.

5.1 Workout types and classifications.

This section presents three practical and relevant workout classifications, which deal with single training sessions in terms of their: (1) organization, (2) training tasks, and (3) load level.

5.1.1 Workout types according to organization

The many possible organization forms used in world-wide coaching practice can be clustered into three basic categories, which are presented in Table 5.1.

Table 5.1
Workout types classified according to their organization

Type	Form of organization	Possible benefits
Group workout	Collectively performed workout according to strictly programmed design or flexible plan	Team spirit, emotional attraction, use of competitiveness and partnership
Individual workout	Programmed workout managed by the coach	Focusing the coach's and athlete's attention on proper details of workload/technique
	Programmed workout managed by athletes themselves	Reduction of emotional strain, workout performed at convenient time and place
	Free or semi-free workout without strict plan	Liberation of self-initiative, self-regulation of load level
Mixed workout	Combination of two previous organizational forms	Training diversity, possibility of combining benefits of the forms presented above

As can be seen in Table 5.1, each form of organization and corresponding workout type has its specific benefits as well as its specificity and limitations. Group workouts as an organizational form allow coaches to administer maximal workloads; this is the type most frequently used in training camps and in so-called centralized preparation, where a number of similarly ranked athletes train together. Of course, this is the prevailing form in team and combat sports. It should be noted that long-term preparation using group workouts exclusively has clear psychological and neurophysiologic limitations. When athletes train with high motivation, competitiveness and prolonged emotional strain can lead to excessive and chronic excitation of the central nervous system and eventually to emotional exhaustion. This is why it is essential to find a harmonious blend of collective strictly programmed workouts and other types of workouts.

Individual workouts are used both for highly ambitious and strictly programmed training (as with the group training mentioned above) and for more liberal and less strenuous preparation. Certainly, the utilization of individual workouts is higher in individual sports than in team and combat sports. Moreover, in several sports like figure skating individual workouts form almost the entire preparation program of highly qualified athletes. Nevertheless, even in team sports individual workouts contribute to the preparation program as a whole. In soccer, basketball, ice hockey etc. pre-season preparation of world-class players is their own responsibility. World-class stars have to find their own facilities, coaching assistance and workout time-table, which are usually individual.

Example. A highly professional and successful soccer player, underwent a one-month specialized mesocycle during off-season at age 30-33 yrs to develop maximal velocity. For this purpose he engaged a highly qualified track and field sprint coach, who planned, supervised and evaluated his training. This training cycle consisted of individual workouts managed by the coach and partly by the athlete himself. This focused work allowed the athlete to maintain a high level of maximal speed despite difficulties caused by aging and previous injuries. (Mark Tunis, personal communication)

Mixed workouts are frequently used in many sports. In individual sports the individual part of the workout is usually utilized for perfecting technique, restoration and relaxation; in team and combat sports the individual parts of workouts are usually devoted to conditioning training, acquisition of some technical skills and relaxation.

One more example. The legendary Edson Arantes Do Nascimento (Pele) said in an interview for a documentary: "Frequently I remained after the workouts and perfected shots, passes and playing with the head" ("Pele Forever", Directed by Anibal Massaini Neto, Brasilia, 2004). It would be fair to say that the combination of team-work and individual virtuosity was what made this sport genius so outstanding.

Many factors determine the proportions of the types of workout organization to be employed, such as: sport specificity, training facilities, number of athletes being supervised by the coach, availability of individual instruments for self-supervision like the "Polar Watch", stoppers etc., the possibility of combining indoor and outdoor exercises in one session, and certainly each athlete's particularities and preferences in terms of working in groups or individually.

5.1.2 Task related classification

Sport practice requires that we differentiate workouts in terms of prevalent tasks. A task related classification is presented in Table 5.2.

Table 5.2
Task related classification of workouts

Types	Objectives	Notes
Conditioning workouts	Improvement of motor abilities, general and/or sport specific motor fitness	This type is predominant in many sports; it is often combined with technical tasks
Technical workouts	Acquisition of new technical skills, perfection of movement technique	This type focuses on movement excellence and requires indicators of quality
Tactical or techno-tactical workouts	Acquisition of new tactical (or techno-tactical) skills, perfection of individual and/or team tactics	Physical and mental exercises can be combined; theoretical sessions can be included as well
Workouts-exams	Evaluation of athlete's abilities	Sport-specific competitive conditions can be simulated
Combined workouts	Developing various athletic abilities combining different tasks.	Two options: 1) sequencing different workout types; 2) combining different tasks in certain exercises

Conditioning workouts devoted to the development of general and sport-specific motor abilities form the major part of training programs in many sports. Very frequently these workouts include technical demands although without particular stress. This workout type can be performed in different organizational formats, such as group or individual workouts managed by the coach or by the athletes themselves.

Technical workouts usually require more attention and organizational efforts. The acquisition of new technical skills such as the perfection of movement technique needs real-time evaluation and immediate correction in successive attempts. Certainly, this work should be thoroughly controlled by the coach or specially engaged experts; hence, individual self-managed workouts are not suitable for this purpose. An additional factor affecting the complexity of technical workouts is the use of visualization means like videotapes in order to provide athletes with objective information about performance quality and meaningful details about proper technique. It should be emphasized that motor learning such as movement technique perfection requires high mobilization of athletes' cognitive and coordinative abilities. Therefore, this workout type causes a particularly heavy load on athletes' central nervous system that should be taken into account during planning.

Tactical or techno-tactical workouts are focused mostly on the acquisition of new tactical skills and the perfection of individual and/or team tactics. One more function of these workouts is the linking of tactical and technical skills, which is extremely important for successful performance. Several parts of tactical workouts can be practiced in class as part of theoretical and mental preparation. However, the major part of this work should be planned and thoroughly implemented in sport-specific conditions where competitive stressful situations can be partially simulated. This type of workout is more characteristic of team and combat sports, where the importance of tactics is relatively higher.

Workouts-exams are intended mostly to evaluate athletes' physical and technical abilities with regard to specially selected components of preparedness (like sport-specific strength or endurance) or in artificially designed situations, which maximally approach conditions in the forthcoming event. As these sessions demand maximal efforts from athletes, this type of workout should be carefully arranged and provided with the appropriate equipment in a suitable environment and with maximal cooperation within the coaching staff.

Combined workouts are devoted to developing a number of athletic abilities (e.g., physical and technical or physical and techno-tactical) within one workout. For example, the first part of a workout can be focused on motor learning while the second is devoted to conditioning training. Similarly, a workout-exam can be followed by a conditioning workout. Another possibility for creating the combined workout is to link up different training tasks in special sport-specific exercises. The widespread approach presupposes simultaneous development of sport-specific motor ability and perfection of appropriate technical skill. These training means of combined two-sided effect are termed *conjugated exercises*. Usually such conjugation is provided in the form of velocity resisted and velocity assisted exercises (Maglischo, 1992).

Example . Exercises with additional resistance are widespread and popular in particular in cyclic locomotions like running, swimming, canoeing, rowing etc. Usually these exercises are directed towards improving force application within a sport-specific technical skill and enhancing appropriate muscular endurance. The velocity resisted approach can usually be realized with the help of relatively inexpensive equipment. Velocity assisted exercises are supposed to facilitate high speed regimes and often, to break the so-called “speed barrier”. The combined effect of such drills is the enhancement of sport-specific speed technique and improvement of maximal speed or event-specific speed endurance.

5.1.3 Aim-Load related classification

From the viewpoints of planning and training analysis the load-related differentiation of workouts is of particular importance. For practical purposes, it is necessary to enumerate three general functions of workouts: development, retention and restoration. The appropriate load level selected should correspond to these aims. In actual fact, each training plan is a specific combination of these workout types: some are intended to enhance development, others are necessary to retain certain capabilities at the previously attained level; and special sessions should be planned for restoration. Therefore, the aim-load related workout classification has a practical advantage. Table 5.3, based on Zatsiorsky's load-related classification (1995), presents quantified workouts on a scale of 1 to 5 reference points where 1 represents the lowest load and 5 the highest (Table 5.3).

Table 5.3
Quantification of workouts: Aim-Load related classification (based on Zatsiorsky, 1995; modified by Issurin, 2003)

Workout aim	Training load level	Restoration time, hr	Load assessment, Reference points.
Development	Extreme	> 72	5
	Large	48-72	4
	Substantial	24-48	3
Retention	Medium	12-24	2
Restoration	Small	< 12	1

The load related aspects of this classification need additional clarification with regard to the desirable time duration for full restoration. The main limitation relates to workouts associated with considerable psychological and neuro-physiological effort. The classification presented above uses the time needed for full restoration as an objective indicator of load level. In fact, this approach pertains to conditioning training such as strength, power, endurance, and speed exercises. High-level coordination training and workouts that induce heightened neuro-emotional stress usually require less time for full restoration; however it is not always possible to select integrative objective markers and indicators based exclusively on the duration of restoration. Nevertheless, the generally approved approach presupposes a series of several workouts, which corresponds to the desired load level according to pedagogical and sport specific estimations. For this purpose, Borg's widely used scale of perceived exertion (Borg, 1973) can be adapted to qualify workouts according to their load level (Table 5.4).

Table 5.4

Qualification of workout load level using Borg's Rate of Perceived Exertion (author's modification)

RPE values	Verbal load qualification	Type of workout
6 7 8 9 10 11	 Very Very Easy Very Easy Fairly Easy	 Restoration
12 13 14	 Slightly Difficult	 Retention
15 16	Difficult	Development – substantial load
17 18	Very Difficult	Development – large load
19 20	Very Very Difficult	Development – extreme load

Following both of the above load-related classifications at least two practical and relevant consequences can be noted:

1) The load level of each workout can be quantified and expressed numerically; this can give additional planning benefits particularly in non-measurable sports (ball games, gymnastics etc.) and allow stronger emphasis of the importance of specially selected workouts;
2) The practical implementation of the load-dependent categories of development, retention, and restoration workouts allows better differentiation between different training sessions and a more deliberate selection of appropriate workloads.

5.1.4 Key-workouts as the decisive development training sessions

The BPC pays particular attention to the design of training composed of several workouts. The principle of high concentration demands that training loads be focused on a minimal number of targeted abilities (see 4.2.2). Unlike the traditional training approach, where the total volumes of performed exercises are of primary importance, the BPC postulates absolute priority of the "total number of development workouts" as the crucial characteristic.

Example. A highly qualified canoeist needs to develop basic aerobic endurance. For this purpose he has to perform 40-45 km weekly volume of exercises at near-anaerobic threshold level. Following the traditional approach this mileage can be divided among nine workouts, where these exercises will be combined with drills for other training modalities (anaerobic glycolitic endurance, strength endurance, maximal speed etc.). The athlete performing this program will be permanently fatigued but the training effect will be small to negligible. The BPC requires a concentration on target-specific exercises mostly within three-four development workouts, which can not be combined with any anaerobic glycolitic tasks. The athletes will sometimes (but not always) be fatigued after strenuous development workouts and the training effect will be more favorable.

According to the BPC, quality of training is strictly determined by the quantity and placement of development workouts. Moreover, some of them should be specially stressed and carefully arranged through appropriate planning. The most important development workouts, which are focused on the current main training directions, are called the "*key-workouts*".

For a long time leading coaches have selected and emphasized several workouts which form the peak-points of corresponding training cycles and concentrate on the most important tasks and workloads. Such peak sessions, recently renamed "key-workouts", also require athletes to concentrate mentally and emotionally and to be ready to work harder than usual.

Example. Tim Noakes (1991), a world known sport physiologist, formulated a number of training rules based on the experience of greatest middle- and long-distance runners such as Herbert Elliott, Ron Clarke and Frank Shorter. The first one is: "Alternate hard and easy training days". This is very similar to the coaching concept of key-workout, which can be expressed as: "Alternate particularly stressful workouts with less hard and easy sessions".

Therefore, the principle of workload concentration postulated for BPC as a whole should be implemented for several workouts as well. The basic characteristics of the key-workout are presented in Table 5.5.

Table 5.5
Basic characteristics and particularities of key-workouts

Basic characteristics	Particularities
Targets	The most relevant abilities are targeted in this training cycle, usually one target related to motor fitness, and one more to technique or tactics
Mental factor	Special motivation of athletes to be focused on a particular workout that strongly determines the effect of the whole training program
Timing	Key-workout is planned for the "best time": a moment when the athletes have adjusted to preceding loads but are still not overly fatigued
Load level	According to the demands of the development workout: substantial or large or extreme level
Organization forms	Partnership, cooperation within group and team spirit are particularly desirable
Training monitoring	Thorough and objective recording of relevant information (using such instruments as chronometry, HR monitors, blood lactate, video…) or using visual signs and pedagogical estimation

As can be seen from Table 5.5 key-workouts require special attention in terms of methodology, organization and psychology. These sessions should contain the most effective and indicative exercises; very often their results can be utilized for training control and for estimating athletes' working potential.

It is not recommended that key workouts include previously unknown training means or completely new conditions, which demand preliminary adjustment. Athletes should be focused on maximal quality in their work; new means and conditions can divert athletes' attention from load-specific details and reduce motivation level. All performance demands, organizational details and work conditions should be clearly explained prior the workout. This holds true for any training session but is particularly important in key-workout.

5.2 Workout structure

Despite the variety and specificity of various sports there are general rules about how each single workout should be compiled. Knowledge of workout structure belongs to the most comprehensive part of training theory, which all coaches begin to learn from their initial experiences in their own athletic career. Indeed, everyone knows that a single workout consists of *warming-up* (introductory part), the *basic part* where planned workloads are performed; and *cooling-down* (concluding part). This general structure pertains to all possible combinations of organizational forms and exercises and has been described by many authors. Nevertheless progress in sport science and practice has led to a more complete understanding of facts which once seemed very simple and now appear more sophisticated. Thus, the essence and content of each workout component can now be elucidated with greater perspective.

5.2.1 Warm-up

The great New Zealand coach Arthur Lydiard included the chapter on warming-up in the book he wrote with Garth Gilmour (2000). There he mentioned that world renowned Australian coach Percy Cerutty, who had worked with multiple world record holder and Olympic running champion Herbert Elliott, was asked after a lecture about the role of warming-up. The authoritative coach answered that rabbits don't warm-up but can run "like the very devil". The anonymous coach from Abilene College who had asked the question took this reply critically and conducted a special study.

Case study. The Abilene coach found a warren and filmed a rabbit's behavior prior to its running activity. When rabbit came out from its burrow, it looked around (moving its head and stretching its neck and back muscles) and trotted forth and back several times. Afterwards the rabbit started to run across the field. Thus, the rabbit really performed a warm-up although not as seriously as human runners (Lydiard & Gilmour, 2000).

It would be fair to say that nowadays very few coaches or athletes still doubt the necessity of warming-up. However, the evidence of effective models and combinations are required. To this end, as is usual in high-performance training, two major approaches exist: summarizing experience from around the world, and reviewing the outcomes of thoroughly designed investigations. The second approach can be illustrated by the findings of a long-term study conducted with high-level athletes.

Case study. Twelve National division soccer teams (180 players) were subdivided into two groups. The first one used a modified training program where warm-ups and cool-downs were carefully compiled based on the outcomes of previous studies: ball exercises were combined with stretching program; cool-downs consisted of jogging and hold-relax stretching. The preparation was supervised by doctors and physiotherapists. The second group contained six teams, which trained traditionally and served as the control. The results of a six month follow up revealed highly significant superiority for the modified preparation program (Figure 5.1). There a marked four-fold reduction in the number of injuries and a drastic decrease of workouts and games missed due to musculoskeletal disorders (Ekstrand et al, 1983).

The above study can be considered as non-typical because it refers to the complex effects of warming-up, cooling-down and medical supervision. Usually the scientific approach deals with separate effects of several factors and what their outcomes can contribute to practice. For instance:

- incorporating stretching exercises in warm-up increases the range of motion of soccer players' lower extremities (Moller et al., 1985);
- active warm-up without stretching doesn’t affect flexibility and is therefore insufficient (Zakas et al., 2006);
- prior intense exercise substantially stimulates aerobic metabolism in working muscles during subsequent strenuous performance (Bangsbo et al., 2001).

On the other hand, the experience of advanced sport practice remains a very valuable source for how to organize warm-up in a particular sport.

Insert Figure 5.1 about here

The warm-up as an introductory part of each workout has three general functions: metabolic adjustment, technical and coordinative adjustment, and mental readiness (Table 5.6). Certainly, metabolic adjustment should be sport-specific; however this does not mean that this warm-up function is important for runners and not for shooters, for instance. In fact the thermal and energetic changes are absolutely necessary for subsequent serious work even though the character and content of these actions are sport-specific. The important role of metabolic adjustment in preventing musculoskeletal damages should also be mentioned. Interviews with prominent coaches in various sports reveal that at least half the incidence of musculoskeletal injuries (low-back, shoulders, knee-joints, ankles etc.) are partially or completely caused by insufficient warm-up. On the other hand, adequate accommodation of appropriate metabolic systems strongly determines the effectiveness of subsequent workloads in the basic part of a workout.

Table 5.6
The main functions, objectives and expected effects of athletes’ warm-up
(based on deVries, 1986; McArdle, Katch & Katch, 1991; Powers & Howley, 1994).

Function	Objectives	Expected effects
Metabolic adjustment	To accommodate all metabolic systems for subsequent efforts and to prevent musculoskeletal damages of unwarmed	Elevation of muscle and core temperature; viscose resistance of muscles and resistance of the vascular bed decrease with heating; hemoglobin and myoglobin link up more oxygen;

	tissues	oxygen uptake increases
Technical and coordinative adjustment	To activate the central and peripheral nervous systems and prevent injuries due to failure in highly coordinative skills	Muscles contract and relax faster, muscle perception and all motor control links are enhanced; basic biomechanical characteristics and movement technique become more stable and economical
Attaining mental readiness	To mobilize the athlete and group for conscious work; to attain appropriate motivation for certain tasks	Attainment of mental concentration towards forthcoming workloads; improvement of mental and emotional self-control

Similarly, technical and coordinative adjustment is an indispensable function of warm-up in any sport; its role in preventing athletes' injuries will be considered below in detail. The third function of warm-up is also essential and its importance is particularly high in sports and workouts where mental and cognitive components play the leading role, such as ball games, combat sports, acquisition of new technical skills etc.

Warm-up in any sport is subdivided into two parts, general and specific, which are characterized by a corresponding selection of exercises' content (Table 5.7). The general part of warm-up usually starts with setting goals for the forthcoming workout and this is the time when the most substantial details of workloads and organization should be explained. High-performance athletes usually have their own style of warming-up, hence they perform their standard combination of exercises. Nevertheless, sometimes several details of the general workout should be accentuated, for instance: prolonging the general part due to lower external temperature (simply stated, cooled athletes need more time to warm up); including additional exercises because of previously injured muscles or joints; more careful exercising of specific muscle groups that are still painful after the preceding training session etc. Indications of the desirable state that should be induced by this part of workout are increased heart rate (up to 110-130 b/min), slight perspiration, increased breathing frequency and pulmonary ventilation, improvement of general body state. The general warm-up usually lasts 8-15 min.

Table 5.7
General and special parts of warm-up: content and particularities

Part	Content, typical exercises	Particularities
General	Low- and medium-intensity cyclic exercises (running, jogging, skipping etc.); calisthenics – various exercises with full range of motion involving major muscle groups and all joints mostly without additional weighting or resistance	Can be performed individually or in small groups; duration about 8-15 min depending on external temperature and individual demands
Special	Sport-specific exercises affecting predominant metabolic systems and technical (and/or techno- tactical) skills to be engaged in the basic part of workout	Can be performed under the coach's supervision; duration about 10-20 min

The initial part of warm-up should usually include a few low- and medium-intensity exercises in order to raise blood circulation, increase body temperature and facilitate oxidation processes in working muscles. It is commonly believed that warmed muscles and connective tissues are more easily extended and respond positively to stretching exercises. Thus, the next step includes stretching exercises where active dynamic stretching (swings, arm and upper body rotations etc.) precede passive stretching. The general warm-up continues with moderate effort strength exercises usually performed without weighting, although exercises with a partner's resistance can be utilized.

The special part of warm-up is very focused on sport-specific metabolic and/or technical particularities of the forthcoming workout. The specially selected drills should activate coordination mechanisms that are involved in the technical skills utilized in the basic part of the workout. In addition, these exercises should assist in stimulating mental readiness for subsequent motor tasks of higher complexity. From this viewpoint, these exercises are important for preventing failure in highly coordinative skills and, therefore, they contribute to preventing injuries.

Despite the variety of possible warm-up versions two alternative modes exist and are practiced by creative coaches in various sports (Table 5.8).

Table 5.8
Two alternative modes of special warm-up prior to the workout

Mode	Content	Benefits
Standard warm-up	Completely standardized program comprising accustomed exercises and tasks in a specific sequence	Performance economy; relatively short duration, simple organization
Particular (non-standard) warm-up	Modeled pre-event warm-up or another non-standard plan including relatively new or attractive elements	Breaking routine, tuning for extra-ordinary forthcoming program

The most frequently used mode is the *standard special warm-up* comprising accustomed exercises and tasks in a specific sequence. Such a warm-up is a part of the routine; it needs no additional motivation, is simply organized and usually lasts 8-15 min. Highly qualified athletes have usually their own standardized warm-up and even a number of appropriate versions for event-specific needs.

Example. Weightlifters perform individually standardized special warm-ups for snatch and another for clean-and-jerk. The content and duration of these versions is individually tailored by athlete and coach. Similarly gymnasts use the proper version of special warm-up for each gymnastics discipline like rings, floor exercise, vault, parallel bars etc. Of course, the relatively constant content and duration of these warm-ups is modified depending on external factors (temperature, humidity etc.) and internal conditions (fatigue, previous injury, anxiety etc.).

The *particular special warm-up* tends to emphasize the extraordinary character of further work. This can be a specially arranged workout-exam where a quasi-competitive situation is stressed. Correspondingly, the modified pre-event warm-up can be managed. The extraordinary key-workout can also be preceded by a particular warm-up that is intended to stress the exclusive character of this session. Similarly, extraordinary events like local festivals, public presentations etc. can be the reasons for using a particular warm-up. It is worth noting that frequent utilization of a particular warm-up leads to a loss of its uniqueness and reduces its stimulatory effect.

5.2.2 Basic part of workout

The basic part of workout is sometimes called the “loading phase” because it concentrates all the real workloads planned for the session. Thus, the desired acute responses should be obtained here from the athletes as a result of properly selected and correctly performed exercises and tasks. These responses can be characterized by objective indicators of the cardiovascular system (Heart Rate), metabolic state (blood lactate), emotional tension (Galvanic Skin Response), performance estimates (speed, performance time, movement rate etc.), and subjective signs of effort and/or fatigue (Rate of Perceived Exertion etc.). Each of these indicators can reflect the general tendency: attainment and maintenance of the highest level for this session load. The basic part is the longest one in the workout and usually lasts about 60-90 min. Of course, during this time interval the load level should be altered properly.

Depending on sport specificity, the basic part of the workout can contain a large number of exercises (as in track and field, swimming or gymnastics) or just one task (such as a match in ball games). Since a long time prominent coaches in different sports strived to compile workouts by selecting and emphasizing the most important exercise or task. The coaches termed this “the meaningful exercise”, “the chief link of the workout”, “the main task”, “the highlight of the program” etc.

Example. A few decades ago the great track and field coach Arthur Lydiard offered a number of weekly programs for different running disciplines and ages (Lydiard & Gilmour, 2000). These programs offered only one exercise in each single workout. Obviously, a workout program for runners does not contain only one exercise; what Lydiard did was to pinpoint only the most important drill. Similarly, typical weekly training reports of great running stars display one exercise in each workout which means that the athletes report only on drills of primary importance (Noakes, 1991)

From the viewpoint of block training, the emphasis on key-function drills is very characteristic. Following the principle of training workload concentration (4.2.2) the accentuation of a specially selected exercise is logical and desirable. Following the principle of a minimal number of ability-targets, usually one selected exercise or task should be particularly accentuated. Similarly to the definition of the key-workout, this main meaningful element of workout is termed the *key-exercise*. In several sports like ball games or combat sports, where the key-function frequently belongs not to a given exercise but to a sport-specific task (training match, training fight etc.) the most important workload is the *key-task*. The major characteristics and particularities of key-exercises (tasks) are presented in Table 5.9.

Table 5.9
The major characteristics and particularities of key-exercises (tasks) in a workout

Major characteristics	Particularities	Comments
Target	Corresponds to the main target of a given workout	Usually only one key-exercise (task) should be selected
Motivation	It requires maximal self-motivation and maximal moral	Athletes should be familiar with the key-exercise (task) in order

	support of the coach	to generate the desired mental concentration
Timing	The best "prime-time" is assigned, when athletes are in the most favorable conditions	High athlete sensitivity allows them to better respond to the workload
Organization	Performance details like interaction of partners, equipment, access to information etc. should be properly provided	Meaningful details (leading, drafting, game scenario etc.) strongly determine the acute effect of the key-exercise (task)
Monitoring	The most relevant performance variables are registering by the coach or his/her assistant	It's important to provide each athlete with relevant exercise-specific information

This coaching concept of key-exercise can be illustrated by the outcomes of a case study conducted during the individual preparation of Gal Friedman, gold medal winner in the sailing regatta at the Athens Olympic Games (Figure 5.2).

Insert Figure 5.2 about here

Case study. Gal Friedman, a world-leading windsurfer, substantially reformed the traditional training approach was based mostly on extensive long-duration workouts at sea. He initiated highly intensive interval workouts, where high efforts were produced by forceful pumping movements, with the athlete producing propulsion by frequent flaps of the sail. The typical key-exercise performed by Gal was: 6 repetitions of speedy performance for 1.5 minutes with 1.5 min intervals of low intensity movement (Figure 5.2). The velocity regime of each performance was controlled, and an HR monitor was used to evaluate the athlete's response. The graph displays repetitive HR peaks at the 178 level with subsequent reduction to 110 b/min, while his personal HR maximum was 198. Therefore, the planned key-exercise was executed at 90% of personal HR upper limit; this load level was definitely the highest in the entire workout (Yanilov-Eden,2005)

Selection of the key-exercise is of primary importance in compiling a workout and offers a professional challenge for coaches. Despite the illusory simplicity of this operation many mistakes have been made in routine work, even by experienced coaches.

Example. A national coaching seminar attended by representatives that had earned many Olympic, World and continental medals, participants were asked to compile a typical workout to develop certain motor abilities. Of the great variety of answers received, more than 50% were incorrect. Even experienced coaches confused exercises for maximal speed and speed endurance (anaerobic glycolitic capacity); exercises for aerobic endurance and aerobic power, etc. Apparently, it was time to refresh this basic knowledge.

It is obvious that describing typical key-exercises for use in any sport is an unrealistic task. Nevertheless, it is possible to characterize the most typical training regimes of key-exercises to develop major motor abilities (Table 5.10).

Table 5.10
The characteristics of key-exercises for developing major motor abilities (based on Fox & Mathews,1981; Viru, 1995; author's modification).

Target-ability	Work interval	Work/rest ratio	Intensity	Number of repetitions	Number of series	Blood lactate, HR
Maximal speed	7-15s	1: 10	Maximal	5-8	2-5	-
Anaerobic glycolitic power	30-50s	1: (4-5)	Submaximal	4-6	2-4	> 8 > 180
Anaerobic glycolitic endurance	1-1.5 min	1:3	High	8-12	1-3	Maximal > 8 > 180
Aerobic power	1-2 min	1: (1-0.5)	Intermediate	5-8	1-3	4-8 160-180
Aerobic endurance	1-8 min	1: 0.3	Medium	4-16	1-3	2.5-4 (5) 140-160
Restoration, fat oxidation	20-90 min	-	Low	1-3	-	1-2.5 100-140

Of course, the format of this chapter and present section does not allow a thorough consideration of the above schematic description of key-exercises. Moreover, very important strength exercises for many sports are not touched up here at all. For these, many other sources in the literature can be recommended. Nevertheless, the general rules highlighted here, irrespective of sport, can assist coaches in compiling their own version of key-exercises and workouts as a whole.

5.2.3 Cooling down

The last, but still compulsory part of each single workout intended to reduce load level gradually and normalize basic functions in the athlete's body is called *cooling down*. Its specific objectives are:

- to reduce body temperature, heart rate and blood pressure back to resting levels;
- to remove acid metabolites and other waste products from the muscles to the circulatory system for further clearance;
- to facilitate recovery of the endocrine system first, by reducing adrenaline and noradrenaline levels in order to prevent restlessness and sleep disorders at night;
- to reduce emotional tension and positively affect athletes' mental recovery.

Generally speaking, cooling down is both an influencing factor and a relevant condition for effective restoration of the athlete. Despite its obvious importance there have been many cases in which this indispensable part of the workout has been ignored, even by successful high-performance athletes. Usually a lack of time is cited as the reason for such mistaken behavior. The previously mentioned study of professional soccer players (Figure 5.2) has shown the role of rational warming-up and cooling down in the protection of athletes' health. As further support, the following study outcomes can be cited.

Case study. Forty-eight adult soccer players were subdivided into three groups, which were tested with respect to range of motion (ROM) in lower extremities before, immediately after, and 24 h after different type of workout. The regular soccer workout caused significant decrease of all ROM indices. A similar workout that included a stretching series in warm-up induced more favorable responses immediately after the session. The third version, where the stretching series was inserted in the cool down, provided significant benefits of ROM immediately after workout and 24 h later. The authors stressed that tight muscles with reduced ROM predisposed athletes to higher risk of injuries (Moller et al., 1985).

In general, the cooling down repertory can be subdivided into three large groups: (1) low intensive exercises, usually slow locomotions like jogging, walking, swimming etc.; (2) breathing and relaxation exercises; (3) and stretching exercises. The particularities of these activities are summarized in Table 5.11.

Table 5.11
Modes and expected effects of various cooling down activities

Mode of activity	Expected effects	Comments
Low intensity exercises	Reduction of body temperature, heart rate and blood pressure; removal of blood lactate and other acid metabolites; decline of adrenaline and noradrenaline level; normalization of blood volume and electrolytic balance	This activity is particularly desired after highly intensive exercises, matches in ball games, fights in combat sports and exhausting long races
Breathing and relaxation exercises	Gradual decline of pulmonary ventilation, reduction of excitation of the central nervous system, recovery facilitation of previously active muscle groups, decline of emotional tension	Combined breathe-relax exercises can accompany jogging or skipping; muscle shaking can be performed in pairs
Stretching exercises	Reduction of training induced stiffness and tightness of muscles, lengthening of previously shortened muscles, increase of muscle and connective tissue elasticity, enhancement of flexibility	These exercises are particularly desirable after plyometric activities, which often elicit delayed onset muscle soreness

The common pattern of cooling down usually starts with slow locomotion that leads to elimination of waste products from the muscles. It has long been known that such activity facilitates recovery and causes faster lactate removal from the athlete's muscles (Bonen & Belcastro, 1976). It is known that highly intensive and prolonged exhausting exercises cause a decrease in circulating blood volume due to water accumulation in intra- and extra-cellular compartments of the muscles (Sejersted et al., 1986). Recovery of the water-electrolyte balance may persist for a long period that in extreme cases (marathon running, for instance) can reach two days and more (Viru, 1995). A rational cooling down procedure can profoundly accelerate this process. Restoration of the endocrine system is a more prolonged process and takes varying periods of time according to each hormone. Exhausting workouts cause pronounced secretion of catecholamines (adrenaline and noradrenaline), which decline rapidly in the restoration period (Hagberg et al., 1979; Jezova et al.,1985). Nevertheless, in extreme cases like marathon or triathlon races increased catecholamine levels can remain for 24 hours and even more (Viru,1995). The increased post-exercise level of catecholamines can cause a number of negative effects like restlessness, sleep disorders etc. A rational cooling down can prevent or at least diminish these unfavorable responses in athletes.

Breathing and relaxation exercises can be performed independently of other activities or they can be combined with slow locomotions like jogging, walking or swimming. The independent option can be realized in drills such as breathing deeply with subsequent relaxation of upper body muscles combined with accentuated expiration. Active arm and leg relaxation can be performed while sitting or lying with the help of a partner who shakes the relaxed extremity at varied frequencies and amplitudes. The combined option can be realized by jogging combined while breathing deeply and shaking arms or legs.

Stretching exercises have frequently been indicated as the primary and most important component of cooling down. Special emphasis has been placed on their role in eliminating post-exercise muscle stiffness and tightness, enhancing muscle and connective tissue elasticity (Shrier & Gossal, 2000). It is commonly believed that stretching can prevent delayed onset muscle soreness that is especially common following exercises with strong eccentric muscle contractions (so called plyometric exercises). This suggestion is supported by several studies (Hartfield, 1985) and contradicted by others (High et al., 1989). In any case the role of stretching exercises in preventing muscle injuries is generally considered to be very important. The stretching protocol is varied and sport-specific. Nevertheless, prominent coaches in different sports recommend performing static stretching and so called hold-relax exercises (passive muscle lengthening with subsequent relaxation) first. These can be followed by dynamic ballistic stretching exercises.

The total duration of cooling down depends on the character and amount of the preceding workload. For instance, blood lactate removal after a 4-min exhausting time trial requires about 20 min of restoration (Juel at al., 1990). This time span approximately corresponds to the cooling down duration. However this period can be insufficient when the workout consists of a number of highly intensive anaerobic series. Usually cooling down lasts about 10-20 minutes; obviously, this duration is not enough after sessions with extreme workloads.

5.3 Guidelines for compiling a workout

How each single workout is compiled is a matter of a coach's personal creativity. Every coach develops his/her own style based on personal experience and accumulated knowledge. Therefore, there is a huge variety of versions even within a given sport. At the same time a number of general guidelines can be offered irrespective of sport. They are highlighted below.

5.3.1 Sequencing exercises for different training modalities

The BPC postulates a reduction in the number of targeted abilities that can be developed simultaneously. However, a unidirectional training design is the privilege of only a very few sports where the number of targets is very limited (for instance, weightlifting does not require the development of many abilities; maximal and explosive strength are dominant and various modes of endurance are unnecessary). The other cases presuppose a sequencing of different workloads within a single workout. From this viewpoint it is important to determine which exercises are preferable for the initial part and which belong in other parts of the workout. The general approach to this choice is based on the physiological demands of various exercises taking into account optimal conditions for best performance (Figure 5.3).

Insert Figure 5.3 about here

As can be seen from the above diagram, several targeted abilities can be successfully developed when the athlete is well rested or slightly fatigued. These include motor tasks, whose performance requires central nervous system (CNS) to be in an optimal state. Exercises for maximal speed, explosive strength, acquisition of new technical skills, and drills to improve neural mechanisms of maximal strength (1-3 RM) require appropriate excitatory neural output that are not available in fatigued athletes. Moreover, fatigued athletes can not respond effectively to these workloads due to inhibitory output from the CNS. Similarly, the highly intensive exercises for anaerobic glycolitic power presuppose availability of sufficient energy resources, which are reduced in fatigued athletes. Exercises for anaerobic glycolitic capacity (speed endurance) demand sustained fatigue despite pronounced accumulations of acid metabolites in muscles and blood. Therefore, a certain level of fatigue is expected and even planned.

The acute effect of aerobic power workloads depends on the total duration of exercises performed near to maximal oxygen uptake level. Moderately fatigued athletes can still sustain this metabolic level and, therefore, such dosage can be recommended. Similarly, the acute effect of hypertrophy strength exercising depends on the total amount of degraded muscle protein (rate of catabolism) and the magnitude of mechanical work performed (Zatsiorsky, 1995). Hence, a large amount of high resistance effort is required and, obviously, the last part of these workloads are performed when athletes are fatigued (but not exhausted).

Example. Imagine an athlete who performs large volumes of endurance exercises but needs to maintain his level of muscle mass and strength ability (this is highly typical of endurance sports). The problem is to find appropriate time for the anabolic strength workout so that it will not interfere with the dominant aerobic work and will not detract from fine movement technique. The coach received a recommendation to plan this workout after the medium load endurance session and was very surprised. He knew that maximal strength workout demands “prime time” of rested athletes. This is actually correct, but for strength exercises intended to enhance neural mechanisms (such as 1-3RM). Another goal of the workout is to attain muscle hypertrophy (like 8-10RM), where the crucial factor is not the athlete’s state before workout but recovery conditions after workout in order to provide the anabolic effect. Hence, such sequencing is reasonable and acceptable in practice.

The exercises for strength endurance and aerobic endurance demand sustained efforts despite accumulated fatigue and therefore should be continued as long as possible. The general rule is that motor learning demands optimal state of the CNS and energy recourses; however, several technical features can be improved in highly exhausting workloads. For instance, fatigue tolerance of motor skill, movement economy and technique stability in unfavorable fatigued conditions can be enhanced only in an appropriate state, which should be consciously programmed. Hence, some part of technique perfection can be performed by fatigued athletes. Similarly, stretching exercises are recommended for use in any part of the workout: at the beginning as a part of warm-up, in the middle as active restoration and for improving flexibility, and in the end as a component of cooling down.

5.3.2 Compatibility of different exercises

The compatibility of various exercises with different training modalities within a single workout and within a workout series, is an extremely important factor determining acute and immediate training effects. Negative interaction of several immediate training effects is one of typical disadvantages of the traditional periodization system. Indeed, the complex approach to training design presupposed the administration of exercises with different training modalities in a single workout. For a long time prominent coaches in most sports criticized and refused to implement this approach for high-performance training. The Block Periodization system utilizes a selective but not complex approach to each single workout, where carefully selected training modalities in compatible combinations are planned.

The diagram in Figure 5.4 displays the main compatible combinations of the dominant training modality with several additional ones in a single workout.

Insert Figure 5.4 about here

The compatible combinations need to be clarified:

1) According to the BPC, the workout program should contain no more than three training modalities (usually one dominant, the second one – compatible with the main purpose, the third one – a modality of technique/tactic improvement or restoration);
2) It is postulated that 65-70% of the whole training time of the developing workout should be devoted to one or two chosen training modalities; this condition is important to obtain high workload concentration and to attain sufficient stimulus for a desirable training effect;
3) The typical frequency of workouts in high-performance training (6-12 a week) dictates certain conditions pertaining to the session subsequent to the key-workout; the basic approach to training design is a significant reduction of workload after the key-workout. The alternative approach of planning two consecutive key-workouts, provides very high load concentrations which can be excessive;
4) Workouts for muscle hypertrophy impose very special demands when planning consecutive sessions within the restoration period: the use of high workloads

during this period adversely affects the anabolic phase of muscle restoration and eliminates the hypertrophy process. Thus, to obtain the anabolic effect it is necessary to substantially reduce workloads for at least 20 hours and to utilize appropriate restoration means;

5) Limiting the number of training modalities is particularly relevant in high-performance sport: the daily program for juniors may be more diverse, multilateral and, therefore, more attractive.

It is worth noting that reasonably combined exercises allow coaches to emphasize the acute effect of the dominant training modality and/or to exploit the effect of previous exercises in subsequent workloads. A number of these favorable psycho-physiological interactions is shown below (Table 5.12).

Table 5.12
Typical compatible combinations of different training modalities and psycho-physiological factors creating a beneficial interaction of combined workloads

Compatible combinations of training modalities	Psycho-physiological factors affecting load interaction
Aerobic endurance – alactic sprint ability	Brief sprint bouts break the monotony; the sprint effort recruits a wide spectrum of muscle fibers, which remain activated during subsequent aerobic workloads
Aerobic endurance – strength endurance	The increased oxidation can be exploited in strength exercises; a combination of conventional and resistance exercises enriches the training program.
Anaerobic (glycolitic) endurance – anaerobic strength endurance	The glycolitic capacity storage can be effectively used by combining velocity assisted, conventional and high resistance exercises; the mental factors of lactate tolerance are subjected to augmented impact
Alactic sprint ability – explosive strength	The explosive strength components (jumps, throws, strokes etc.) utilized in alactic work intervals accentuate the generation of motor output
Maximum strength - flexibility	Stretching exercises facilitate muscular and mental relaxation, which can be exploited for active restoration within maximum strength workouts
Maximum strength – aerobic exercises	Low intensity aerobic exercises activate metabolic recovery and muscular and mental relaxation, which can be used for restoration during and after strength workout

5.3.3 One day workout series

The planning and performance of a number of workouts each day is widely used and commonly accepted in the preparation of high-performance athletes. Anecdotal reports by several prominent coaches indicate that four, five and even six daily workout series were successfully performed. Of course, a six daily workout series would be an exception but a two- and three-workout series is routine in training camp practice. Practical experience in training design, control and follow up of daily workout series is extensive and objective data are available in the scientific literature. Nevertheless, most of the large amount of empirical data and previously presented scientific background (5.3.2) about how to compile daily series of workouts are directed to developing aerobic abilities (Figure 5.5) or anaerobic abilities (Figure 5.6).

Insert Figure 5.5 about here

The ultimate purpose of subdividing the total daily amount of exercises into three, four and more workouts is to increase the quality of training, i.e., the intensity of exercises and their partial volume, create more favorable conditions for restoration, benefit more from technique improvement in relatively better restored athletes, etc.

Consider the daily series for anaerobic abilities development (Figure 5.5). The first workout contains gradually increasing workloads. Very often athletes suffer from stiffness and soreness of muscles; the light earlier morning workout helps to reduce these negative consequences of previous workloads and prepare them for further serious work. The appropriate technical elements can activate sport-specific sensations and facilitate motor control. The second workout provides favorable conditions for sprint bouts, which positively interact with moderately intensive aerobic drills. A one hour break before the third workout restores athletes for a more concentrated aerobic program. Three hours of rest prior to the final session of the day readies them to perform continuous aerobic drills and the aerobic resistance program despite the fatigue accumulated during previous work during the day. The cooling down program is particularly important in this workout and usually takes relatively more time.

In highly intensive training the hiatus between daily exercise dosage is of particular importance (Figure 5.6).

Insert Figure 5.6 about here

The first workout in a daily series is similar to the example described previously except that brief intensive efforts can be included. The second workout contains highly intensive aerobic power exercises, which cause fast accumulation of acid metabolites and oxygen debt. The one hour break before the third workout provides partial restoration during which about 70-80% of accumulated lactate can be oxidized (Volkov, 1986). Nevertheless the next session starts when athletes are slightly fatigued. It is worth noting that the glycolitic pathway and enzymatic pool are still activated by the preceding workout and this positively affects the second highly intensive workout with its exercises for anaerobic glycolitic capacity (anaerobic endurance). The three hour break following the third workout provides the athletes with partial restoration, although the athletes come to the fourth and final workout fatigued. Consequently, the warming-up and cooling down parts can be markedly prolonged. In the basic part, the anaerobic strength endurance exercises, which entail sustaining progressing fatigue, can be successfully performed. Hence, the daily workout series facilitates the enlargement of the total amount of anaerobic glycolitic exercises and the attainment of a more profound metabolic response.

Similarly the one day workout series can be compiled with regard to various ability-targets such as maximal speed, explosive strength or techno-tactical fight ability in combat sports. It should be noted that the four-workout series under consideration is not as widely practiced as the two-workout daily program routine for high-performance training. The most typical compatible combinations of two sequenced workouts per day are presented below (Table 5.13).

Table 5.13
Typical combinations of compatible training modalities in two workouts per day (the key-exercises are noted)

Dominant targeted ability	First workout	Second workout
Aerobic power and capacity	Fartlek: 10-15 s sprint – 3-6 min work on the anaerobic threshold level	Aerobic interval series
Anaerobic glycolitic power and capacity	Anaerobic power interval series	Anaerobic capacity interval series
Maximal speed	Anaerobic alactic interval series	Anaerobic alactic exercises; explosive strength exercises
Techno-tactical game ability	Techno-tactical simulation, maximal speed	Match

It should be concluded that the one-day workout program, even an extremely important one, is part of a larger training unit (micro-, mesocycle). Its interaction with preceding and subsequent workloads is of particular importance both for planning and performance.

5.4 How to compile a workout

Based on all the material mentioned in this chapter, the general approach to the compilation of each single workout seems very comprehensive. Nevertheless, some summation of the relevant information in the form of an algorithm would be helpful. Experienced coaches, who perform this work almost automatically, will be able to compare their proper approach with the formal prescription; young coaches and athletes should accept the basic standard, which can assist them in developing their own style (Table 5.14).

Table 5.14
General algorithm for how to compile a single workout.

No	Operations	Remarks
1.	Determination of main and additional targets, and load level	Should be done for entire microcycle with respect to each workout and their expected interactions
2.	Selection of appropriate organizational form	The expected interactions between the athletes and possible partnership should be taken into account
3.	Compilation of key-exercise (key-task)	This includes prescription of all relevant performance details (velocity, movement rate, expected response etc.)
4.	Selection of all other exercises	All exercises should be checked with regard to their reciprocal compatibility
5.	Selection of appropriate warm-up and cooling down versions	Both warm-up and cooling down can be modified according to workout specific demands
6.	Inspection of available equipment and workout conditions	Monitoring means, training machines, accessories and as far as possible weather conditions should be inspected

Perhaps it is not necessary to prepare a full description of each workout including all the details mentioned in the table, but they should be taken into account in any case. It is most highly recommended to familiarize the athletes with the upcoming workout plan. World famous coach and sport scientist James Counsilman (1968) used to write the workout content on a large blackboard in front of the swimming pool. It was his contention that this definitely raises motivation and affects consciousness to perform heavy workloads. In general, coaches should be ready to explain to curious athletes why they selected certain combination of exercises and not others.

Summary

Workouts often seem to be a trivial and simple component of the training system that need no special consideration or elucidation. In fact, the Block Periodization approach emphasizes several aspects of workout compilation which were ignored or insufficiently considered previously. Thus, for example, the proposed aim-load related classification offers a distinction among three different workout types: development, which provides the major training stimuli for progress; retention that is aimed at maintaining several abilities at the level attained; and restoration, which facilitates recovery after the preceding high-load sessions. The proposed five-point scale enables coaches to quantify workouts according load in any sport, where one point indicates the minimal level and five points – extreme workloads. Based on the experience of prominent coaches' the term "*key-workout*" was proposed and elucidated. It stresses the most important development workouts, which are focused on the main training directions and help facilitate the key-function.

Warm-up and cooling down are considered indispensable structural elements of a workout. This chapter stressed the role of warm-up in metabolic and technical adjustment, mental readiness and preventing injuries. Similarly, the cooling down was considered from the viewpoint of restoration and injury prevention. The basic part of the workout was described with regard to the main meaningful content element which was termed the *key-exercise (or key-task)*. The methodic, psycho-physiological and organizational aspects of key-exercise are also presented. Guidelines for compiling the workout are given with respect to sequencing and reciprocal compatibility of different exercises. Thus, exercises for maximal speed, explosive strength, acquisition of new technical skills, and drills to improve neural mechanisms of maximal strength (1-3 RM) require appropriate excitatory neural inflow and should therefore be performed when athletes are not fatigued. Exercises for anaerobic glycolitic endurance and maximal oxygen uptake can be fulfilled by moderately fatigued athletes who can still sustain the desired metabolic level. Exercises for strength endurance and aerobic endurance demand sustained efforts despite accumulated fatigue and can therefore be continued till the end of the workout. An important point is that the Block Periodization Concept presupposes minimization of training modalities within a workout: one dominant modality, a second one that is compatible with the main purpose, a third one to improve technique/tactics or provide restoration. Usually 65-70 % of all training time in the development workout should be devoted to one-two specific training modalities. Compatible combinations of different training modalities within single workouts are presented. Special attention was given to one day workout series that can embrace two-six sessions. Factors such as load sequencing, exercise compatibility and possibility of athlete restoration are taken into consideration. In addition there are given the general guidelines of how to compile daily series of workouts and the most typical compatible combinations of two sequenced workouts in a day.

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Chapter 6. Micro-, mesocycle and training stage

The microcycle is the shortest training cycle. It encompasses a number of workouts and lasts a number of days, often one week. The mesocycle, a medium size training cycle, incorporates a number of microcycles. A number of mesocycles in a specific sequence and with purposeful interaction form a training stage that is usually directed to competition. This chapter presents and elucidates the basics, essentials and design of the various training units.

6.1. Microcycles

As stated above, the microcycle usually lasts one week. This uniformity has no physiological rationale but rather is based on social life; athletes combine training with education and professional activity, and their normal desire to spend weekends with family and friends. However training camp conditions make it possible to create shorter and longer microcycles; these possibilities will be considered below. Our attention in this chapter will be directed to types and specification, load variations, compatibility of adjacent workouts, and, in particular, the content of various microcycles.

6.1.1. Types and specification

Six types of training microcycles are characterized by specific purposes, load level, particularities of workload design and duration (Table 6.1).

Table 6.1.

Purpose, load level and particularities of different microcycle types.

Type	Purpose	Load level	Particularities	Duration
Adjustment	Initial adaptation to appropriate loads	Medium	Gradual increase in workload	5-7 days
Loading	Fitness development	Substantial - high	The use of big and substantial workloads	5-9 days
Impact	Fitness development by extreme training stimuli	Very high - extreme	Use and summation of extreme workloads	4-7 days
Pre-competitive	Immediate preparation for competition	Medium	Tuning for forthcoming competition; use of event-specific means	5-7 days
Competitive	Participation in competition	High – very high	Sport and event-specific performances	2-7 days
Restoration	Active recovery	Low	Use of the wide spectrum of restoration means	3-7 days

As can be seen from Table 6.1 the microcycles differ in purpose, load level, particularities of design, and even in duration. For instance, the adjustment microcycle at the beginning of season usually lasts a whole week. In the middle of the season this microcycle can be planned at the beginning of a new stage or to start the training camp. In both cases its duration can be shorter (3-5 days) and depends on proper circumstances of preparation. It should be noted that gradual increase of load level relates not only to physiological demands (i.e. magnitude of training stimuli) but also to the mental load component. This can be particularly important for the training camp, where athletes receive new cognitive and emotional demands simultaneously. Similarly, the restoration microcycle varies in its duration depending on fatigue level and demands of preparation. Usually in mid-season, the restoration microcycle after training camp and/or after competition lasts 3-4 days.

The loading microcycles encompass mostly routine work; they usually last one week but this duration is not compulsory. Load administration in this cycle will be considered separately in the next section. The impact microcycle focuses on maximal load; that is why it can last less than a whole week. Special requirements should be arranged for supplying restoration means, which are necessary for such microcycle programs to achieve their goals. Proper diet, nutritional supplements, hydrotherapy, massage, mental relaxation etc. can be parts of a special restoration program. A pre-competitive microcycle can also be shorter or longer than a week. It is normally directed in two important directions: to provide mental, physical and techno-tactical tuning for a forthcoming event, and to provide full (or sometimes partial) recovery of athletes after previous serious loads. Consequently, this microcycle is characterized by a remarkable load reduction. The competitive microcycle is exclusively sport-specific; this determines its content, particularities and duration which, in extreme cases, can be more than one week, as in many-day road cycling competitions. For instance, the world famous cycling “Tour-de-France” lasts twenty three days including two days off. Thus, this competition embraces three successive microcycles. The sequencing of different microcycles will be considered in 6.2.

6.1.2. Load variations within microcycle (wave-shape designs).

It is commonly known that the load level should be varied within a microcycle. The main factors determining load variations are load summation, which causes fatigue accumulation, and restoration, which is affected by the use of reduced load level workouts and other restoration means. Previous considerations of load variability have been based on general load categories such as “small, medium and high" load levels (Martin,1980; Starischka, 1988) or in percentages of maximum (Dick,1980; Platonov,1997; Bompa,1999). Adequate and integrative load description is a problem, particularly for non-measurable sports like sailing or ball games. The 5-point load scale presented in the previous chapter (5.1.3) makes it possible to formalizing workload alterations within several microcycles. Let’s consider typical load variations in microcycles with one workout per day (Figure 6.1).

Three- and two-peak designs are used most widely because they allow athletes to perform relatively large amounts of weekly workloads with relatively reduced risk of excessive fatigue accumulation. The load reductions (three or two respectively) facilitate athletes’ restoration and stimulate their readiness to effectively perform subsequent high demand workouts. The key-workouts concentrate on the most important workloads of dominant training modalities.

Insert Figure 6.1 about here

The one-peak design can be employed to concentrate a number of developing workouts in order to obtain a more profound and stressful training response that can be exploited as preparation for further medium- and low-level workouts, where several technical and/or tactical tasks can be fulfilled combined with gradual recovery. Such a concentration of one-peak developing workouts can definitely be offered to sufficiently prepared high-performance athletes but not to novices and less prepared sportsmen.

When athletes practice two or even more workouts a day the daily point-score is contributed to by each workout; thus making the weekly point-score much higher (Figure 6.2). The graph displays load variation within a microcycle, where each coordinate summarizes load values of one or two single workouts for several day. The load value for each single workout is based on a 5-point scale. The first peak is created by two successive developing workouts followed by two supporting workouts of medium load level, which give the possibility of restoration prior to the second mini-block of workloads comprised of three developing sessions including two key-workouts. The last session (on Saturday) can be devoted to a time-trial or a match in ball games, or some other competitive simulation.

Insert Figure 6.2 about here

Additional remarks can be made about a quantification system based on a 5-point scale. Its utilization offers a number of possible benefits:

First, the graphical workload presentation (particularly in non-measurable sports) gives additional support for coaches as they analyze the load level of each workout and qualify it more accurately; different microcycle constructions (one-, two-and, three-peak designs) can be expressed numerically and presented in visual form.

Second, the microcycle graph can be used didactically; athletes can relate more consciously to training demands; they can better realize the importance of key-workouts and anticipate the possibility of restoration after the stressed load peaks.

Third, the total point-score of the whole microcycle can be used for general load evaluation and for comparing different microcycles. In this manner, planning technology can be enhanced.

As previously stated, the Block Periodization approach presupposes a high concentration of specialized workloads directed at a minimal number of targeted abilities (4.3). It is obvious that this determines special demands for appropriate microcycles, which should offer mostly separate but not complex administration of workloads taking into account their reciprocal interactions and expected training residuals. Therefore, the next paragraphs are devoted to considering the most widely used aerobic (or strength-aerobic) microcycle (6.1.3), anaerobic glycolitic microcycle (6.1.4), maximal speed microcycle (6.1.5), and microcycle of sport-specific strength abilities (6.1.6).

6.1.3. Microcycle to develop aerobic (strength-aerobic) abilities.

Aerobic and so called strength-aerobic microcycles incorporate a large part of overall preparation in many sports, with a contribution of aerobic endurance and muscular strength to athletic performance (i.e. all endurance sports, combat sports, ball games, several aesthetic sports like synchronized swimming and figure skating etc.). The combination of aerobic and strength exercises needs special clarification. On the one hand this combination reduces strength enhancement in comparison to strength training alone (Zatsiorsky, 1985). On the other hand, strength training itself increases muscle mass that has relatively low oxidative capability (Wilmore & Costill, 1993 and others). Hence, enlarged muscle mass that is not supported by a proportional increase in aerobic enzymes and mitochondrial mass will give no benefits to athletic performances in many of the above mentioned sports. Of course, the proportion of aerobic and strength exercises within a microcycle can vary depending on athletic demands and/or individual desires. Let's consider the particularities of the strength-aerobic microcycle in the preparation example of many-time World and Olympic swimming champion Alexander Popov (Russia).

Example. Alexander Popov, one of the greatest swimmers specializing in 50 and 100m Freestyle sprint events, has drawn a lot of attention to aerobic and strength workloads. Aerobic microcycles form the essence of his training in the preparation phase, corresponding to the accumulation mesocycle in Block Periodization terms.

Figure 6.3 displays the training modalities of exercises performed in ten full workouts. Popov's typical strength-aerobic microcycle highlights the large amount of exercises up to the Anaerobic Threshold (AT) level and technical drills (Tech) directed at stroke perfection. These technical drills were performed while counting strokes and targeting a number of movement cycles for each velocity regime; they effectively affected both technique and swim-specific strength. Maximal Speed (MS) exercises (anaerobic alactic) were performed each day in medium proportion, while Aerobic Power (AP) exercises were planned for only three workouts. Strength Endurance (SE) drills, i.e. aerobic velocity resistance exercises, were another large contributor to the program. Anaerobic Glycolitic (AnG) exercise was employed once as the time trial on 200m all-out in the stepwise incremental test (by courtesy of Guennadi Touretski, personal communication).

The above example provides evidence that: a) even in the training of a prominent sprinter, the contribution of aerobic endurance exercises is very high; b) developing strength abilities can be effectively provided by means of force accentuation in sport-specific drills; c) despite the high contribution of anaerobic glycolitic power and capacity in the metabolic profile of 100m Freestyle performance, the engagement of anaerobic glycolitic exercises to the strength-aerobic microcycle program is negligible. The last circumstance is particularly important in light of Block Periodization. Indeed, the athlete's body can not respond effectively to training stimuli that simultaneously affect very different physiological systems. Highly intensive glycolitic workloads cause a profound metabolic response and hormonal shift, which can last two-three days (Viru, 1995). Superimposition of training responses beyond aerobic and glycolitic anaerobic exercises leads to conflict in the adaptation process. Moreover, highly accentuated aerobic exercises are intended to create profound physiological changes like muscle capillarization, and increased aerobic enzymes, myoglobin and mitochondrial volume. All of these changes occur during post-exercise recovery; the addition of anaerobic glycolitic workloads leads to a discrepancy in metabolic adaptation and dramatically decreases the cumulative training effect.

Insert Figure 6.3 about here

As was already stated, the Block Periodization approach postulates minimizing the targeted abilities within one mesocycle (consequently in the microcycle as well). Compatible training modalities in aerobic microcycle are: maximal strength (first priority), anaerobic alactic (maximal speed) abilities, aerobic strength endurance (as a part of aerobic potential), and movement technique (Table 6.2).

Table 6.2.
Aerobic microcycle: compatible training modalities with respect to training design and methodical backgrounds

Training modalities	Training design	Methodical backgrounds
Maximal strength	Strength workouts demand sufficient recovery for	Linkage of aerobic and strength workouts ensures better oxidation in

	anabolism	enlarged muscles
Anaerobic alactic (maximal speed) abilities	There are two options: alternating exercises and inclusion of alactic sprint series	Sprint bouts break monotony and activate a wide spectrum of muscle fibers that can be exploited in subsequent aerobic workloads
Aerobic strength endurance	Use of velocity resisted exercises in appropriate metabolic regimes	Additional resistance (weighting) stimulates force application in power phases of movement
Movement technique	Learning of new skills; accentuation of technical details in performing drills	Perfection of technical skills doesn't aggravate metabolic adaptation to both aerobic and strength workloads

In planning strength workouts in the aerobic microcycle, it is important to remember that its effectiveness depends on the testosterone/cortisol ratio, which affects protein synthesis in skeletal muscles. After endurance workloads this ratio remains decreased for many hours, an unfavorable time for carrying out strength workouts (Viru, Karelson & Smirnova, 1992). On the other hand, high-resistance workouts increase the rate of protein turnover, which persists for at least 24 hours (Chesley et al., 1992). Therefore, developing workouts for maximal strength should not be performed in the shadow of preceding exhaustive aerobic training and 24 hours of recovery must be provided during which time only low-level loads can be managed.

Anaerobic alactic exercises do not have primary importance in the aerobic microcycle but their contribution is far from negligible. Sprint bouts being used in alternating exercises (like fartlek) recruit the fast motor units, which are normally inactive in drills of moderate intensity (Komi, 1989). The short-term oxygen debt caused by this spurt should be compensated during subsequent aerobic work; thus additional stimuli for oxidation receive both low and fast muscle fibers. The break of monotony and the elevation of emotional intensity in the aerobic workout are also valuable contributions of sprint exercises.

The large amount of moderately intensive exercises is intended to carry out many technical drills directed at enhancing basic technical details and elements. Such features as automatization, biomechanical economy, full range of motion, accentuation of force application in power phases and enhancement of relaxation phases, rational variability following changed conditions, and fatigue tolerance can be successfully affected during prolonged aerobic exercises.

The chart of a typical strength-aerobic microcycle (Figure 6.4) presents the general approach to training designing taking into account the above mentioned demands for high-resistance workouts.

Insert Figure 6.4 about here

6.1.4. Microcycle of highly intensive anaerobic workloads.

Microcycles of highly intensive anaerobic workloads form the content of the most specific and exhaustive transmutation mesocycle. As was already mentioned (4.2.x) the cumulative training effect of such training is highly dependent on the selection of compatible training modalities, which make it possible to reinforce and accomplish the influence of dominant workloads (Table 6.3).

Table 6.3.
Anaerobic glycolitic microcycle: compatible training modalities with respect to training design and methodical backgrounds

Training modalities	Training design	Methodical backgrounds
Strength endurance (mostly anaerobic)	High-resistance drills can be included in regular workout or/and managed in separate sessions	High-resistance intensive exercises produce dual effect: developing strength endurance and enhancing anaerobic metabolism
Anaerobic alactic (maximal speed) abilities	The favorable well restored state usually can not be found; sprint bouts can be used by moderately fatigued athletes	Alactic mechanism contributes to power output of short-duration bouts where the main target is maximal glycolitic power; sprint bouts provide diversity and enrich training
Low intensity aerobic exercises	There are managed in each part of the workout and in separate sessions	Indispensable component of active restoration program that also includes stretching, relaxation etc.
Movement technique	Combination of technical demands with dominant workloads; accentuation of the most meaningful technical details	Highly intensive loads and fatigue accumulation suppress technical skills; particular measures are necessary to prevent these negative consequences
Tactics (focus on ball games and combat sports)	The most stressful techno-tactical tasks get prime-time both in session and microcycle	Combination of techno-tactical demands with physical strain elicit profound sport-specific training effects

A few remarks can be made with regard to the summarization in Table 6.3. First, the developing workloads in this microcycle are performed at a load level higher than anaerobic threshold. Nevertheless, the extent of anaerobic recourse mobilization may vary and depends on many factors. Normally the strain level over the microcycle gradually increases as the target competition approaches. Hence, the utilization of workloads inducing lactate accumulation in the 5-8 mM range makes it possible to improve maximal aerobic power and aerobic-anaerobic interaction; these workouts can be prevalent in early- and mid-season. The workloads that elicit lactate accumulation over 8 mM are directed to enhancing anaerobic glycolitic power and capacity; they contribute highly to the program in the final stages prior to the target-competition.

Second, high-resistance intensive exercises can comprise the essential part of a training program. Typical drills such as uphill running, serial jumping, resistance swimming, rowing, paddling etc. activate the entire spectrum of muscle fibers. The recruitment of fast motor units leads to a rapid increase in lactate production; as a result the extent of anaerobiosis in such workloads is relatively higher and duration for sustaining the given load level is shorter. Thus, the intensive strength endurance workout is an important contributor to an anaerobic microcycle of a training program.

Third, anaerobic alactic exercises are compatible with an anaerobic glycolitic program, with restrictions. They require proper metabolic, enzymatic and neural adjustment that can not be sufficiently provided within an exhausting and strictly managed microcycle. However, specific demands of several sports (in particular in ball games and combat sports) dictate involvement of short-duration bouts (alactic) and more prolonged efforts (glycolitic). In addition, the use of short-duration sprints makes it possible to diversify the training routine although without attempting to enhance maximal speed ability.

Fourth, the metabolic stress typical of highly intensive anaerobic exercises makes it more difficult to perform proper technique and techno-tactical skills. However, similar (or even more pronounced) aggravation occurs during competitive performance. Hence, these skills should be properly enhanced with respect to extreme physical and emotional exertions, i.e. within the framework of highly intensive workload microcycles.

As was stated and emphasized, the principal salient features of the anaerobic microcycle are fatigue accumulation and insufficient restoration. Indeed, Block Periodization postulates a high concentration of the training program on a reduced number of targeted abilities. Highly intensive glycolitic workloads cause the most pronounced training reactions, namely: (i) in the cardiovascular system - attainment of maximal heart rate and cardiac output (Noakes,2000); (ii) in energy supply - maximal oxygen deficit and debt, the maximal increase and accumulation of blood lactate (Saltin, 1986; Astrand et al., 2003); (iii) in hormonal regulation - rapid increase of adrenalin, noradrenalin and cortisol while testosterone level decreases for a period of 24 and more hours (Viru, 1995). Taking into account workout frequency (6-12 per week) and post-exercise recovery duration, fatigue accumulation over an entire microcycle is inevitable. To reduce the negative consequences of insufficient restoration the following methodical guidelines are proposed:

a) the sequencing of developing workouts should be thoroughly examined from the viewpoint of expected fatigue accumulation;
b) restoration workouts are a very important ingredient of a training plan; they should be distributed reasonably;
c) the inclusion of restoration entails appropriate exercises (stretching, relaxation, low intensity drills etc), massage, physiotherapy; nutritional supplements are strongly recommended;
d) the monitoring of athletes' training response has particular importance here.

Based on the above and taking into account the optimal timing for different training modalities (Figure 5.4), many versions of the microcycle plan can be compiled. The general chart of an anaerobic microcycle containing ten workouts is presented below (Figure 6.5).
Insert Figure 6.5 about here

A number of essential details can be mentioned with regard to the proposed design:

a) A microcycle contains six developing workouts directed at anaerobic glycolitic power and capacity and strength endurance with an anaerobic component; three key-workouts are focused on these three training modalities;
b) The key-workouts are secured by preceding them with medium load sessions or a restoration "window" on Wednesday evening; subsequent restoration workouts are intended to prevent excessive fatigue accumulation until the microcycle ends;

c) Anaerobic alactic abilities are stressed in two workouts of medium load with the intention of maintaining the upper limit of speed ability; both restoration workouts are compiled with low intensity drills, also intended to support or enhance the sport-specific technical skills;
d) It can be noted that load variation in the chart corresponds to a three-peak design; it is likely that two- and three-peak variations are the most suitable for microcycles of highly intensive anaerobic workloads.

6.1.5. Microcycle for explosive strength in highly coordinative exercise.

Unlike so called metabolic sports, where energy production plays a decisive role on athletic performance, the highly coordinative power sports have very specific demands for fatigue accumulation. Both neuro-muscular specificity of these sports and the salient manifestations of explosive strength presuppose a suitable background for developing workouts and, consequently, for high workload microcycles, namely: sufficient sensitivity and reactivity of the central nervous system (Zatsiorsky, 1995), rapid replenishment of energy resources (Wilmore, Costill, 1993), appropriate hormonal status, i.e., a beneficial testosterone/cortisol ratio (Viru, 1995). Therefore, the microcycle of highly specific workloads that is typical for the transmutation mesocycle substantially differs from the equivalent microcycle in endurance sports. The typical disciplines in the power sports category are throwing (discus, javelin, hammer, shot put) and jumps (high, long, triple and pole vault). Let's consider the typical microcycle for developing explosive strength in a highly coordinative discipline using the hammer throw as an example.

Example. The microcycle under consideration is taken from the preparation of two-time Olympic champion and Olympic silver medal winner Yuri Sedyhk (USSR). The microcycle contains a total of eleven workouts, where all developing sessions are directed exclusively to explosive strength, event-specific technique and maximal strength. The content of the microcycle was reported by the athlete's personal coach (Bondarchuk, 1986) – Table 6.4.

A study of this microcycle reveals a number of essential details, which can be considered characteristic of this type of training:

a) The event-specific explosive strength exercises, which are of primary importance in the entire program, are placed exclusively in morning sessions and always in the initial part of the workout; this approach reserves the most favorable phases of the athlete's state for performing the most important key-exercises;
b) The maximal strength exercises, which play an important supporting role for event-specific power and athlete's condition, were employed in five sessions: four times separately in special evening workouts and once in the second part of the morning session;
c) Additional explosive strength exercises (standing jumps) were performed three times but not in the athlete's most favorable condition;
d) Restoration exercises (playing basketball, swimming, stretching) were organically involved in the training program; even the vacation day included a restoration session.

Table 6.4.

Microcycle of highly specific workloads in the preparation of Olympic champion Yuri Sedyhk for the hammer throw (based on Bondarchuk, 1986)

Day	**A.M.**		**P.M.**	
	Content	Training modality	Content	Training modality
Mon	Throwing hammer of different weights, 30 throws; Standing long jumps	ExpS + Tech ExpS	Running spurts of 5-20m Barbell exercises: snatch, half squats, "good morning" exercise Stretching	ALA MS
Tue	Throwing hammer of different weights, 30 throws	ExpS + Tech	Barbell exercises: rotary torso, half squats; Standing jumps	MS ExpS
Wed	Throwing of 16 kg weight, 25 throws; throwing of shots using different techniques, 50 throws. Playing basketball – 15 min	ExpS Rest	Off	
Thu	Throwing hammer of different weights, 35 throws Barbell: snatch, half squats, "good morning" exercise, rotary torso. Swimming pool – 25 min	ExpS + Tech MS Rest	Off	
Fri	Throwing hammer of different weights, 32 throws Standing jumps.	ExpS + Tech ExpS	Barbell: snatch, half squats, "good morning" exercise, rotary torso. Stretching.	MS Rest
Sat	Throwing of 16 kg weight, 25 throws	ExpS	Barbell: snatch, half squats, "good morning" exercise, rotary torso. Stretching. Playing basketball – 20 min	MS Rest
Sun	Walking; swimming pool – 30 min	Rest	Off	

Based on the training evidence in this table, it is possible to reconstruct the typical microcycle for developing explosive strength in a highly coordinative throwing discipline (Figure 6.6).

Insert Figure 6.6 about here

It is worth noting that the corresponding microcycle in the jumping disciplines has many specific features like sprint exercises, etc. Nevertheless, the above mentioned particularities (Figure 6.6) remain relevant also for other explosive strength disciplines.

6.1.6. Pre-competitive microcycle

This type of microcycle forms the content of the realization mesocycle (see 4.2.2) and should therefore satisfy the following demands:

a) It uses sport-specific exercises and tasks, which simulate forthcoming competitive activity; it attains mental readiness and toughness;
b) It develops maximal speed (power) abilities and sport-specific quickness;
c) If offers full restoration after highly fatiguing workloads in the preceding transmutation mesocycle.

One more demand relates to mental readiness for forthcoming competition; its importance increases as the competition approaches, although mental preparation is incorporated into the training process at earlier stages as well.

Because the pre-competitive microcycle is part of the realization mesocycle, also called the taper, its methodological clarification and interpretation is quite different. Basically it is intended to reduce the total workloads but the proposed ways of attaining this goal are varied. It is generally believed that total training volume should be decreased, however, many contradictions can be found regarding workout duration and frequency for the partial volume pertaining to highly intensive exercises (Kubukeli et al., 2002). The Block Periodization concept makes it possible to propose certain general approaches that can assist in designing the pre-competitive microcycle in several sports (Table 6.5).

Table 6.5.
The major characteristics and particularities of pre-competitive microcycles

Major characteristics	Particularities	Comments
Workload volume	Substantially reduced	This creates conditions for full recovery
Total volume of intensive exercises	Substantially reduced as compared with previous mesocycle	Total volume of these drills decreases to facilitate recovery but the quality increases
Contribution of maximal speed (power) exercises	Substantially increased	Well rested athletes respond better to maximal speed drills; training residuals of maximal speed training are the shortest.
Contribution of sport-specific simulative tasks	Substantially increased	These simulative tasks allow better adaptation to expected competitive stressors
Workout frequency	Usually similar to previous mesocycle	Subdivision of entire work into several portions allows an increase in workout quality
Organization	Rational combination of group, individual and mixed workouts	This should be done with respect to sport-specificity and athlete individuality
Restoration	Beneficial conditions for full	Usually athletes receive more

	recovery; increased volume of restoration exercises/workouts	time and desire to perform restoration exercises

Reduction of workload volume is a principal condition for full restoration, to obtain and then exploit the athletes' state of supercompensation. In other words, to reduce the workload level here is of primary importance; how we do it is based on different circumstances. The main contributors to the desired workload decrease are (1) a reduction in total training volume and (2) a reduction in partial volume of intensive exercises. The proportions are sport-specific and individually dependent, but the output is always similar – restoration and improvement of the athlete's general state. This improved state forms the background for the successful employment of two groups of exercises:

- maximal speed drills (remember that their effect depends on reactivity of the central nervous system and the availability of energy resources), and
- sport-specific tasks simulating forthcoming techno-tactical competitive situations (well restored athletes can better approach model competitive regimes and adjust to expected stressors).

Workout frequency, as a component of the microcycle design, is neither simple nor unequivocal. On the one hand reduced frequency can be considered an instrument to decrease total workloads and to find more time for restoration. However, on the other hand, the division of daily workloads into two portions makes it possible to increase the quality of highly intensive exercises. Moreover, additional free time, particularly in the conditions of a pre-competitive training camp, can be a serious disadvantage to a daily program. Thus, the preferred solution is to maintain the usual daily schedule for these athletes. In qualified athletes, particularly during the pre-competitive training camp, this means performing eight-ten workouts per week.

The forms of workout organization in the pre-competitive microcycle are strongly dependent on the specificity of the sport and individual particularities of the athletes. Of course, in team sports and team events such as rhythmic gymnastics or crew disciplines in rowing and canoeing, group workouts are absolutely dominant. Nevertheless, the general tendency is to a relative increase in individual workouts, where athletes can better concentrate on personal technical details, feelings, responses and proper ways of self-regulation. Moreover, proper contact with the coach in charge affects athletes' self-confidence.

The restoration workouts definitely contribute more to this training plan than in other microcycles. This is explained, first of all, by the importance of the restoration process in the entire taper program and in attaining a supercompensation state for the competition period. In addition, because the time budget is more liberal in the pre-competitive microcycle, there is better exploitation of restoration workouts and exercises as tools to increase the quality of the most important sport-specific sessions.

Special attention should be given to the proper timing of workouts with regard to the expected schedule of competitions. In general, the daily biological rhythmus should be adjusted to the schedule of the forthcoming competition, i.e., the most important workouts should be planned for the time of competitive peak-performances.

Example. The program of canoe-kayak and rowing regattas at the Olympic Games is scheduled exclusively for the morning hours. This is in contrast to the program of world and continental championships in which races are held both in the morning and the afternoon hours. Consequently, pre-Olympic preparation of world-class rowers and paddlers is planned in keeping with the expected time of maximal efforts. This is particularly typical of pre-competitive microcycles, where athletes perform simulative exercises exactly at the time of forthcoming events.

The general chart of the pre-competitive microcycle presented here was compiled for training camp conditions and for expected competitive peak-performance times in the morning hours (Figure 6.7).

Insert Figure 6.7 about here

It is worth noting the particular role of strength exercises in the designing of pre-competitive microcycles. On the one hand many athletes report that high-resistance exercises prior to competitions negatively affect fine technical skills and their number should be diminished or even excluded. This stance is especially typical among swimmers (Platonov, Fesenko, 1990) but also appears among volleyball and tennis players. On the other hand the use of sport-specific exercises for maximal or/and explosive strength allows athletes to maintain the technical force component at the desired level (Bompa, Carrera, 2003). Moreover, proper exercises for muscular hypertrophy prevent uncontrolled reduction of muscle mass induced by stress hormones prior to and during competition.

6.1.7. How to compile a microcycle.

The Block Periodization approach entails several particular considerations concerning microcycle compilation. These relate to the function and importance of key-workouts, namely: determination and compilation of key-workouts, facilitation of workload performance in key-workouts, monitoring the training etc. The restoration process also takes on greater importance because of the preparation involved for highly concentrated workloads and restoration after their performance. In general, the entire process of microcycle compilation can be presented in a sequence of specific operations (Table 6.6).

Table 6.6
The sequence of operations for compiling the training microcycle.

N	Operation	Remarks
1	Determination of dominant and secondary training modalities	This should be based on the annual plan and specificity of the current mesocycle
2	Determination, placement and compilation of key-workouts	These workouts should provide the main developing impact of training
3	Determination of restoration workouts and restoration “windows”	These measures facilitate performance of key-workouts and prevent excessive fatigue accumulation
4	Determination, placement and compilation of other developing and supporting workouts	Workload interaction deserves special attention; preceding workouts affect sensitivity to subsequent workloads
5	Selection of appropriate means for	Targeted abilities and functions are the

	training monitoring and follow-up	focus of monitoring
6	Planning special events	This can involve a psychologist, physician, etc. or a special meeting, etc.

In addition to the above algorithm a number of general rules can be proposed to facilitate the process of microcycle training design.

The first rule – priority of key-workouts. The content and training modality of the key-workouts determine the main affect and direction of the whole microcycle. Thus, when the targeted abilities of a microcycle are clearly defined, the process of training design should start by compiling the key-workouts.

The second rule – arrangement of key-workouts. When compiling the sessions adjacent to key-workouts, their interaction should be taken into account: the preceding workout affects the athlete's sensitivity to developing workloads; the subsequent session determines fatigue accumulation and the restoration process.

The third rule – sharing restoration means. The restoration means, i.e., restoration workouts, restoration exercises (low intensity aerobic exercises, stretching, relaxation, shaking, breathing exercises), and restoration procedures (massage, sauna, hydro- and physiotherapy, mental training) form an indispensable component of training design. These means should be thoroughly planned in the framework of each microcycle.

The fourth rule - workload initiation and peaking. Usually a day-off decreases athletes' readiness for high workloads. Thus, the first session of the microcylcle should not be a key-workout. The number and placement of the key-workouts determine the peak location and their number in the microcycle, i.e., one-peak, two-peak and three-peak design.

The fifth rule - training monitoring. The data from key-workout performance provide the best indication of the athletes' current state: current achievements, technical variables being performed at the required level, athletes' responses, i.e., heart rate, blood lactate concentration, rate perceived exertion, etc.

6.2. Mesocycles

The Block Periodization concept proposes three types of mesocycle (Table 4.7). As elucidated in Chapter 4, their general assessment and interpretation differ considerably from traditional training theory. Indeed, mesocycle-blocks form the essence of the alternative approach. They encompass both the extensive experience of prominent coaches in different sports and new concepts that elucidate modern training (4.2.1). Thus, accumulation, transmutation and realization mesocycles will be considered in light of Block Periodization.

6.2.1. Accumulation mesocycle

As compared with other mesocycles this type is characterized by relatively high volumes of workloads at relatively reduced intensity. As the accumulation mesocycle is intended to develop basic athletic abilities, its duration, content and training monitoring are of particular interest.

Duration. In general, two major factors impact on the length of this mesocycle:

- sufficient time to obtain the desired cumulative training effect in the targeted motor abilities;
- the time limitation dictated by the competition calendar.

It has already been noted that the basic motor abilities developed in the majority of sports are aerobic endurance and maximal muscle strength. Progress in both of these abilities demands profound morphological and even organic changes, and therefore they need sufficient time for this physiological adaptation. However, among qualified athletes at high levels of general fitness, relatively short periods of accentuated workloads provide substantial improvement in these abilities. Thus, it is important to determine the optimal duration for the mesocycle-block that will be sufficient to obtain desired changes but not excessively long so that the next mesocycle can start on time. Let's illustrate this by the outcomes of a relevant case study.

Case study. Eight highly qualified female kayakers were monitored during a twenty week training program aimed at improving maximal strength abilities and aerobic endurance. High-resistance training lasted 4-5 hr/week; monitoring included measurement of maximal isometric force in kayak-specific body positions. The gain in maximal strength and improvement rate differed greatly at the beginning, middle and end of the program (Figure 6.8). The initial three weeks induced average strength progress equal to 5.9%, i.e., an improvement rate of 1.93% per week; the next three weeks caused additional improvement of 1.6% and an improvement rate of 0.53%. The continuation of the program had a very modest impact, where improvement rate decreased to 0.25 and 0.13% per week. Therefore, the entire fitness program was very effective at the beginning, reasonably effective through six weeks and of only minor effect for the next 14 weeks (based on Sharobajko, 1984).

Insert Figure 6.8 about here

Similar trends have been noted during prolonged programs intended to improve aerobic endurance and this corresponds to general biological concept that the adaptive response induced by long-term training declines with time (Bouchard, 1986). All of the above further supports the general idea underlying Block Periodization, that training should be divided into shorter periods and exploit higher improvement rates for developing abilities. On the other hand, the cumulative training effect is characterized not only by gains in specific motor abilities but also by profound changes in physiological systems. This is particularly relevant for early season preparation, when enhancement of basic abilities and functions is of special importance. Therefore, the accumulation mesocycle can be longer (up to six weeks) when training is intended to elicit more profound physiological changes, or shorter (three weeks and even less) when training is intended to stimulate basic abilities and refresh general responses.

The time limits imposed by the competition calendar have a strong impact on mesocycle planning. Early in the season, athletes are usually less dependent on calendar events; in these cases mesocycle duration can be based exclusively on coaching concepts. At mid-season, the timing of important competitions dictates the sequence and duration of training stages; consequently, the accumulation mesocycle can be shortened to three-four weeks; at the end of season important competitions can come at relatively short intervals and the length of the accumulation mesocycle can be reduced to 10-14 days.

Content. The selection and sequence of appropriate microcycles substantially determine mesocycle content in terms of load variation (Table 6.7).

Table 6.7
Selection and sequence of different microcycles (McC) to compile an accumulation mesocycle

Part of mesocycle	Content (types of McC offered)	Comments
Initial	Restoration Adjustment	This McC is suited to initiating a new training stage; not necessary after transition period This McC continues the initial part and can be shorter than a week
Mid- and end part	Loading	The number of these McC determines total duration of whole mesocycle
Options	Impact Restoration	Can be administered in the mid-part with duration about 3-6 days Can be planned immediately after impact McC and followed by loading McC

In general, the load level should be gradually increased in the initial part of the mesocycle; the maximal load level should be obtained and maintained in the mid part. However, in the end part it is better to reduce the load level in order to start the next mesocycle without excessive fatigue. In special cases the restoration microcycle (usually lasting three-four days) can be inserted towards the end of accumulation block in order to start the next transmutation mesocycle in good condition.

Monitoring training. The main purpose is to assess implementation of planned workloads and to evaluate current changes in targeted abilities and athletes' training responses. The general approach to implementation is presented below (Table 6.8).

Table 6.8
Major characteristics and possible indicators for monitoring training in the accumulation mesocycle

Major characteristics	Possible indicators	Comments
Workload	Total mileage per week	To be analyzed:

performance	Total number of sport-specific repetitions per week Outcomes of key-workout	- actual vs. plan; - week to week trend - trend within season
Targeted (basic) abilities	Results in time-trials Results in free weight trials Average results in key-workouts	It is suggested that appropriate valid tests be used
Training responses	Resting Heart Rate Blood urea and CPK Body mass, muscle mass Fat component Blood lactate after the trials and exercises of special interest	The follow up is aimed to reveal that: a) the level of fatigue is reasonable, b) the athletes obtain desired changes in their condition

With regard to Block Periodization, the importance of development and particularly of key-workouts should once again be emphasized. Comparison of key-workouts performed in successive microcycles can be done with respect to exercise volume (mileage, repetitions, sum of the lifted weight, etc.), results of performances (average time of series, average movement rate), and measurable training responses (HR, blood lactate etc.). In addition, the serious strength training that affects muscle hypertrophy causes an increase in muscle mass and perhaps body weight as well; the accentuated aerobic endurance training can reduce the fat component. Therefore, athletes' anthropometric changes can be measurable outcomes when evaluating mesocycle training. Particularly in sports where changes in body mass are undesirable (i.e. gymnastics or sports with weight categories) this information is of special interest and draws much attention. These changes should be thoroughly monitored in order to provide the coach and athletes with valuable information.

6.2.2. Transmutation mesocycle

According to Block Periodization, the transmutation mesocycle contains the most stressful sport-specific workloads. The general idea of this mesocycle is to transmute the accumulated potential of basic abilities into specific physical and techno-tactical fitness. As compared with other types, this mesocycle is characterized by the following:

a) The targeted abilities are more specialized; the key-exercises are tightly connected with competitive activity;
b) The intensity of developing workloads is relatively higher; the partial volume of exercises with increased intensity is higher as well;
c) This is the most fatiguing mesocycle; consequently, employment of restoration means and stress monitoring are of paramount importance.

These features of the transmutation mesocycle determine its duration and content as well as the particularities of training monitoring during its execution.

Duration of this type mesocycle is determined by various factors, which are summarized below (Table 6.9).

Table 6.9
The factors influencing duration of the transmutation mesocycle

Factors	Impact	Comments
Limitations caused by fatigue accumulation	Fatigue produced by highly concentrated intensive workloads approaches the upper border in 3-4 weeks	Excessive fatigue can be obviated by inclusion of a restoration microcycle or an aerobic mini-block
Duration of residual training effect caused by previous mesocycle	After 4 weeks of highly intensive workloads, effect of previous aerobic mesocycle drops dramatically	Residual training effect of preceding mesocycle attenuates with time and decreases markedly after one month (Table 4.6)
Limitations caused by competition calendar	The short time period between important events requires a shortening of the mesocycle	In this case mesocycle duration depends on calendar restrictions

As can be seen in Table 6.9, the transmutation mesocycle as the training block of highly specialized intensive workloads usually lasts no more than four weeks. The dominant factors limiting its duration differ depending on the proximity of important competitions: in early season duration is affected mostly by fatigue accumulation, at end-season mesocycle duration is determined by the calendar of important events, and in mid-season both of these factors affect duration in varying proportions. The duration of training residuals induced by a previous accumulation mesocycle has a rather complicated, complex influence. On the one hand, basic motor ability potential (aerobic endurance, maximal muscle strength) decreases and approaches the critical level over four weeks. Consequently, if the transmutation mesocycle and subsequent realization mesocycle last six weeks the athletes will come to competition with attenuated aerobic and strength potential. On the other hand many sport disciplines require that a large amount of anaerobic glycolitic workloads be managed over a more prolonged period. This methodic contradiction can be surmounted by including a short-term aerobic mini-block within a prolonged anaerobic mesocycle (see 6.3.3).

Content of the transmutation mesocycle is formed by a number of sequenced microcycles, which are characterized in general below (Table 6.10).

Table 6.10
Selection and sequence of different microcycles (McC) to compile a transmutation mesocycle

Part of mesocycle	Content (types of McC offered)	Comments
Initial	Loading	The load level gradually increases during the initial McC (usually one week)
Mid- and ending part	Loading and/or Impact	The Impact McC can last less than a week (3-4 days)
Options	Competition (trial) Restoration Aerobic contrast mini-block	Participation in competition under fatigue is not excluded This McC can be inserted after impact McC and followed by loading McC This McC (2-4 days) can be included to prolong aerobic training residuals

As can be seen from Table 6.10, the transmutation mesocycle is formed mostly of loading microcycles; administration of the impact microcycle can be moderate as well. Inclusion of some competition can vary the program. Often the competitive workload is lower than in the usual training routine, so that athletes consider this event to be one of load reduction. In addition athletes are aware that nobody expects their personal best in such events, which diversifies hard training work. Inclusion the of restoration microcycle can be planned in advance or administered individually for athletes as they approach their upper limits of adaptation. Inclusion of a contrast aerobic (or strength-aerobic) mini-block makes it possible to prolong attenuated training residuals and partly restore athletes for subsequent highly intensive training.

Monitoring training is especially intended to prevent excessive fatigue accumulation and overtraining. It is important to monitor performance of the training program and evaluate current achievements in sport-specific exercises. The general approach to this is presented below (Table 6.11).

Table 6.11
Major characteristics and possible indicators when monitoring training in the transmutation mesocycle

Major characteristics	Possible indicators	Comments
Workload performance	Total volume of exercises Partial volume of intensive exercises Outcomes of key-workout	It is important to show that athletes perform planned work with special respect to key-workouts and individual drawbacks
Targeted (sport-specific) abilities	Results in sport-specific series Results obtained in key-workouts	In non-measurable sports, qualitative evaluation is highly desirable
Training responses	Resting Heart Rate Self-estimation of fatigue, stress, sleep, muscle soreness Blood urea and CPK Body mass, muscle mass Fat component Blood lactate after the trials and exercises of particular interest	Maximal workloads elicit maximal training responses, which should be taken as feedback. Subjective ratings of fatigue, stress, sleep and muscle soreness give the coach valuable information. Of course, high confidence between coach and athlete is very important.

It should be emphasized that dose and upper limit of adaptation are the biggest problems of the transmutation mesocycle. On the one hand this training cycle concentrates the highest sport-specific workloads, the performance of which substantially determines each athlete's individual progress. On the other hand it is very difficult to determine the upper limit of adaptation that athletes should not exceed. Even evaluation of hormonal state and other blood markers does not unequivocally guarantee a timely diagnosis of overtraining. One of the most comprehensive definitions of overtraining was given by ex-world record holder, Olympic champion runner and sport physiologist Peter Snell, who declared: “Overtraining may be regarded as a state in which performance diminishes while the level of training is maintained or increased” (Snell, 1990). According to this explanation, the person who decides about overtraining is the coach. From the coach's viewpoint, it is very important to recognize the generally accepted warning signals of the early phase of overtraining. They are: (1) an increase in resting HR of more than 5 beats/min over a three-five day period; (2) persistent or rapid decrease of body mass;

(3) persistent increased rate of general fatigue; (4) persistent increased rate of muscle soreness; (5) persistent increased rate of sleep disturbances (Burke et al., 1990; Hooper et al., 1995).

> **Case study**. Nineteen elite swimmers were monitored during a 6-month preparation using a large battery of blood and urine markers, hormones, CPK, resting blood pressure and HR, and event-specific all-out tests with blood lactate determination. In addition all swimmers made daily entries in their log-books of swim volume, time of dry-land workout and subjective ratings of stress, fatigue, sleep quality and muscle soreness on scale of 1 point (very, very low or good) to 7 (very, very high or bad). During the study three athletes were diagnosed as overtrained. However, the difference between stale and non-stale swimmers was not reflected in any blood, urine or other markers during mid- or late-season. Nevertheless this difference was significantly revealed through fatigue and muscle soreness ratings. Moreover, the multi-component statistical model embracing the mean ratings of stress, fatigue, sleep quality and muscle soreness was able to predict changes in competitive performance. Interestingly, the use of a larger battery of indicators did not increase the accuracy of prediction (Hooper et al., 1995)

This example shows that sometimes even simple inexpensive methods (i.e. subjective ratings of stress, fatigue, sleep quality and muscle soreness), if used systematically and responsibly, provide effective training monitoring that is particularly desirable in the high-load transmutation mesocycle.

6.2.3. Realization mesocycle

As previously mentioned, traditionally the realization mesocycle is termed the *taper*. In traditional periodization the taper is used prior to important competitions and is intended to stimulate better performance. According to the Block Periodization concept, the realization mesocycle forms the concluding phase of each training stage and, therefore, its function is broader. On the one hand it is directed to obtaining peak-performance and in this aspect it does not differ from the usual tapering technique. On the other hand, this mesocycle concludes a carefully designed program consisting of several training stages in which all the important components were intentionally developed (see Figure 4.8). It is obvious that the training stages in early- mid- and late season are not identical. Correspondingly, the realization mesocycles also differ depending on the level and importance of the forthcoming competition. This determines essential particularities of the mesocycle such as its duration, reduction of workloads, emotional tension of athletes etc. These particularities are summarized below (Table 6.12) and are considered briefly.

Table 6.12

Major characteristics and particularities of the realization mesocycle

Major characteristics	Particularities	Comments
Aims	Peak-performance attainment, full restoration prior to competition, completing the	Demands for peaking depend on level and importance of

	training stage program	forthcoming competition
Abilities-targets	Maximal speed (quickness), event specific tactics, readiness to compete	Well rested athletes are more able to effectively develop these abilities that require higher reactivity and concentration
Workload level	Much lower than in preceding mesocycles	There are various approaches to reducing workload level
Duration	One-three weeks	Depends on importance of competition and sport-specific factors
Techno-tactical behavior	The use of sport-specific modeled exercises (tasks)	These tasks have to form proper techno-tactical competitive behavior
Emotional tension and anxiety	Elevation pending the competition	Extent of elevation depends on the level of forthcoming competition
Training monitoring	Following up time-trials, evaluation of techno-tactical behavior, training responses and level of restoration	The current control is focused on: a) integrative sport-specific estimates; b) individually important traits and features
Nutrition	The use of nutritional supplements and control of energy intake	This is intended to produce an ergogenic effect and to prevent unfavorable changes of body mass and composition

The realization mesocycle leads to the transmutation mesocycle where the maximal amounts of workloads are performed. Consequently, athletes initiate the mesocycle program when they are fatigued. Hence, chronologically the first aim is to provide and facilitate restoration and ultimately to obtain a supercompensation state at the time of competition. It is important to remember that the targeted abilities, which should be the focus of the mesocycle program, demand high sensitivity and reactivity of the central and peripheral nervous systems, availability of energy recourses and mental concentration. These preconditions of proper development occur in well rested athletes. Therefore, reduction of workload level is of paramount importance at the initiation of the realization program. There are different approaches to how the workloads can be reduced. The salient factor that affects the rate of workload reduction is duration of the mesocycle. A short mesocycle demands a fast workload decrease, a more prolonged mesocycle can be planned with a gradual reduction of workload level. The duration itself, on the other hand, is extremely important and sensitive. A long-duration mesocycle can lead athletes to detraining; an excessively short mesocycle may not be sufficient to restore and develop event-specific abilities. This contradiction was specially considered (Mujika et al., 2004).

Simulation and enhancement of techno-tactical competitive behavior is an obligatory component of the realization mesocycle program in many sports. Despite the striking specificity of various sports, the general idea of techno-tactical simulation is very similar – adjusting athletes to planned or expected competitive behavior. Consequently, techno-tactical simulation programs should meet the following demands: (i) the competitive situation (race pattern, tactical combination, techno-tactical task etc.) should as closely reproduced as possible in the exercise; (ii) the level of athletes' concentration should approximate competitive levels; (iii) the number of simulation performances should be sufficient to attain stable and reliable techno-tactical skills. The typical techno-tactical tasks and their dosage in the realization mesocycle for qualified kayakers are presented below (Table 6.13)

Table 6.13

Techno-tactical race simulation in a two-week realization mesocycle for qualified kayakers

Typical tasks for techno-tactical race simulation	Total number
Quasi-competitive race performance	4-6
Race simulation in broken series (four quarters divided by 20s breaks)	8-12
Selective simulation of initial quarter of the race	10-16
Selective simulation of mid-distance race pattern (two mid- quarters)	8-12
Simulation of pre-event warm-up program	3-5

Emotional tension and anxiety are attributes of pre-event preparation. Of course, their occurrence refers mostly to later in the season, where the importance of the competitions and the necessity to do well in them approach maximum. It is worth noting the contradictory impact of pre-event tapering on the emotional state of athletes. There is considerable evidence that workload reduction during the taper causes a remarkable improvement in mood associated mainly with improved athlete recovery (see review of Mujika et al., 2004). However, pre-competition anxiety can change this trend dramatically at least in terms of two generalized factors: (i) a moderate level of anxiety facilitates performance and positively affects athletes' behavior while excessive anxiety detracts from performance; (ii) the effects of such emotional stimulation depend on the athletes' level; elite athletes benefit more than sub-elite from increased anxiety, whereas mid-class sportsmen can be attenuated by emotional tension (Raglin & Wilson, 2000).

Training monitoring has a number of mesocycle-specific features, which are associated with the dominant training modalities and particularities of pre-competition preparation (Table 6.14).

Table 6.14

Major characteristics and possible indicators for monitoring training in the realization mesocycle

Major characteristics	Possible indicators	Comments
Workload performance	Total number of sprint repetitions Total number of sport-specific simulations	All these characteristics should be compared with the plan and the individual history of each athlete.

	Total number of quasi-competitive performances	It is likely to assess the quality of performance
Targeted abilities	Results in maximal speed tests Results in event simulation tests Relevant techno-tactical estimates	It is important that the test outcomes are comparable with similar preceding mesocycles
Training responses	Heart Rate and Blood lactate after the relevant exercises Resting Heart Rate Effort perception CPK and blood urea level	Acute post-exercise response characterizes individual reserves and perfection trend. CPK and blood urea indicate the level of restoration
Athlete's state	Sleep quality and mood state Body mass Fat component	Sleep and mood questionnaire can be used. Body mass and fat are of special interest in sports with weight categories.

Although the realization mesocycles within the annual cycle are not identical, the similarity of the training monitoring program offers a number of visible benefits for athlete preparation as a whole:

- The coach can select, check and validate the entire set of tests and indicators; individual norms for each athlete can be elaborated;
- Athletes can learn their individual responses in order to better adjust to more stressful situations as the target competition approaches;
- Methods of self-regulation, mental training and body mass reduction (if necessary) can be learned in advance and adjusted individually.

Nutrition during the realization mesocycle draws special attention to balancing dietary intake and energy expenditure. As was already emphasized, workload reduction is highly characteristic of this mesocycle. Correspondingly, energy expenditure decreases significantly while athletes' nutritional habits often remain unchanged. As a result energy intake can surpass energy expenditure causing a remarkable increase in the fat component.

Case study. Twenty highly qualified male long-distance triathletes were followed up during a four-week mesocycle with high workloads and a subsequent two-week tapered mesocycle with reduced workloads. Body mass, body fat, energy intake and expenditure were evaluated. It was revealed that average energy intake of athletes remained at the same level, whereas energy expenditure decreased during the tapered mesocycle by up to 69.3% (Figure 6.9). Nevertheless, mean body mass of the group didn’t change while body fat mass increased by 4.3%. The imbalance of dietary intake and energy expenditure caused remarkable fat accumulation. However, it can also be suggested that their muscle mass decreased as well and body mass remained at the previous level. Therefore: a) body mass as an indicator of anthropometric state is not always reliable; b) pre-competition reduction of training workloads demands much attention to athletes' nutrition, which should correspond to the decreased energy expenditure (based on Margaritis et al., 2003).

Insert Figure 6.9 about here

In conclusion, the realization mesocycle definitely has the lowest level of workloads; however, the level of emotional tension during this time span can be much higher than during the usual training routine. Consequently, this emotional factor can substantially modify both athletes' behavior and their training responses.

6.3. Training stage

According to Block Periodization, three consecutive mesocycle-blocks form one single training stage. Its length depends on the duration of each mesocycle and varies from 4-10 weeks. As was already noted (4.2.3), the training stage reconstructs the entire annual cycle in miniature, allowing for the consecutive development of basic abilities (as in the preparation period), specific abilities (as in the competition period), and integrative readiness for event-specific performance. The most favorable superposition of residual training effects makes it possible to obtain the optimal combination of basic, special and event-specific abilities when needed at the moment of competition (Figure 4.8). However, if the training design will be based exclusively on the length of training residuals, the result will be an extremely rigid and non-flexible construction. In fact there are additional factors influencing training residuals and additional methods to prolong them.

6.3.1. Competition within the framework of the training stage.

It is known that not every competition is planned for peak performance. Some of them are intended to include extraordinarily high workloads, to break the training routine and to add emotional diversity to the preparation. Thus, competition can reasonably be included in the accumulation and transmutation mesocycles. However, their influence is equivocal. Pronounced highly intensive competitive efforts produce profound physical and emotional stress. The secretion of stress hormones like catecholamines and cortisol modulate athletes' metabolic response and reinforce the catabolic process (Viru & Viru, 2001). As a result muscle mass and maximal strength can decrease. Moreover, the highly intensive anaerobic glycolitic efforts typical of competitions suppress the activity of aerobic enzymes and the oxidative process in the mitochondria (Volkov, 1986). For a long time, this impairment of aerobic fitness has been noted by prominent coaches, rather intuitively, who administered special aerobic workloads to restore and regenerate the athletes after competition. A recent publication elucidates the negative effect of competition in light of shortening training residuals (Issurin & Lustig, 2004).

Case study. The preparation of many-time Olympic and World swimming champion Alexandre Popov was monitored using an incremental stepwise swimming test. The anaerobic threshold velocity was determined according to a blood lactate level of 4 mM and a velocity corresponding to 8 mM as the lower limit of highly intensive glycolitic workloads. These indicators were evaluated at the beginning of a mesocycle with highly concentrated aerobic workloads, ten days after this evaluation, and a few days after the competition where Alexandre performed several times (Figure 6.10). At the initial stage of this study the remarkable gain of both anaerobic threshold velocity and velocity corresponding to 8 mM was noted. However, remeasurement of these estimates after competition revealed a substantial decrease, which can be attributed to a shortening of training residuals, induced by the previous program (adapted from Pyne & Touretski,1993).

Insert Figure 6.10 about here

To conclude this section, the following relevant positions are worth noting:

1) Incorporating mid- and low-level competitions in the training stage is an important and meaningful component of the entire preparation;
2) Competitive performances elicit superior and profound athletes' responses that enrich the adaptation spectrum of the training routine, however;
3) Highly intensive competitive efforts produce the secretion of stress hormones that modulate metabolic and hormonal responses, thus shortening residual training effects of the preceding mesocycle. This should be taken into account in the subsequent program.

6.3.2. How to prolong residual training effects

Inasmuch as the training stage is a sequence of three mesocycle-blocks, the crucial factor that restricts the duration of a particular stage is the length of residual training effects after the first accumulation mesocycle, which lasts about 30 days (Table 4.6). This timing predetermines the total duration of the second and third mesocycles, which should be not longer than the training residuals of aerobic and strength workloads, i.e., one month. However, in many sports the transmutation mesocycle is directed at reinforcing anaerobic glycolitic abilities, which should take three-four weeks; moreover, the duration of the realization mesocycle (taper) can last about two weeks. In this case the duration of both of these mesocycles (about five weeks) exceeds the length of the strength-aerobic training residuals and athletes may approach the targeted competition at a reduced level of basic abilities. It is obvious that some special measures should be undertaken to prolong the training residuals of the strength-aerobic program. One might imagine that this prolongation can be attained by additional supporting workouts for aerobic endurance and/or muscular strength. In fact such attempts don't succeed. The background of the highly intensive transmutation mesocycle strongly suppresses the immediate effect of developing aerobic training; similarly, anabolic strength exercises require sufficient restoration that can not be provided. Apparently, what should be inserted in the mesocycle is not several workouts but a special compact mini-block (short microcycle), in order to prolong training residuals. This principal approach is displayed below (Figure 6.11).

Insert Figure 6.11 about here

Example. Imagine a situation in which two targeted competitions have a five-week interval between them (this situation is very typical for kayaking where the European and World championships are separated by an interval of five-six weeks). In this case of inflexible time limits you can plan 10-14 days for accumulation, 10-14 days for transmutation, and 8-10 days for realization mesocycle. Here you need not include mini-blocks because the training residuals following the accumulation mesocycle surpass the term of competition. Another situation occurs when you are forced to plan a training stage for a period of 7-9 weeks (this situation is very typical for pre-Olympic preparation in several sports, where the international calendar has no competitions before the great event). In this case it is reasonable to plan longer mesocycles and the inclusion mini-blocks would be necessary.

Summary

Microcycles as the shortest training cycles are differentiated in three principal directions: loading, competing and recovery. The microcycles devoted to the first direction differ according to load level: *adjustment* that serves to adapt athletes for increasing workloads; *loading* that intends to develop athletic abilities, and *impact* that employs extreme training stimuli. The second direction contains the *pre-competitive* microcycle, which prepares the athlete for forthcoming competitions; and the *competitive* microcycle, where the athlete takes part in the competition. The third direction is obtained with the special *restoration* microcycle. The microcycles can be managed with respect to different load variations. More specifically, one-, two-, and three-peak designs can be executed. This chapter deals with the microcycles focusing on: (a)aerobic (strength-aerobic) abilities, (b) highly intensive anaerobic workloads, (c) explosive strength in highly coordinative exercise, and (d) pre-competitive training. These microcycles are considered by means of guidelines for compiling the microcycle program. A number of general rules are proposed for microcycle compilation: (1) priority of the most meaningful key-workouts; (2) interaction of successive workouts; (3) sharing restoration means; (4) initiating and peaking training workloads, and (5) training monitoring.

The three types of mesocycle proposed by the Block Periodization Concept are considered with respect to duration, content and monitoring training. Specifically, the *accumulation, transmutation* and *realization* mesocycles are described with respect to the sequencing of various microcycles; fatigue accumulation that is particularly pronounced in the transmutation mesocycle; the selection of appropriate tasks and exercises, and determination of the most adequate monitoring means for several mesocycles. It is important to remember that athletes' self-estimation of training response in their log-book can provide valuable information for preventing excessive fatigue and even overtraining. Subjective ratings of stress, fatigue, sleep quality and muscle soreness on scale of 1(very, very low or good) to 7 (very, very high or bad) are recommended for systematic use.

The training stage consisting of three sequenced mesocycles reconstructs the entire annual cycle in miniature, where training stimuli are focused first on basic abilities, second on more specific abilities, and third on integrative readiness for event-specific performance. It is essential to remember that competitive performances and emotional strain can shorten training residuals of the preceding mesocycle; this phenomenon was considered through a case-study example of many-time Olympic champion Alexandre Popov, whose anaerobic threshold velocity decreased remarkably after competition. It is noteworthy that including special compact mini-blocks (short microcycles) can prolong residual training effects of the preceding mesocycle. Thus, aerobic mini-blocks can be inserted in the transmutation mesocycle; a highly intensive anaerobic mini-block can be incorporated within the realization mesocycle.

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Chapter 7 Long-term preparation

Long-term preparation concerns periods lasting one year and more. From this viewpoint three major aspects of long-term preparation demand proper consideration: the annual cycle, multi-year preparation of qualified athletes including the quadrennial cycle, and multi-year preparation of juniors. This chapter will present and elucidate the basic positions and planning guidelines, in brief, pertaining to these three aspects.

7.1 Annual cycle

The planning of the annual cycle in terms of Block Periodization was described generally in chapter 4 (see 4.2). Special attention should be given to the technology of planning and guidelines for training design.

7.1.1 Goal, aims and basic directions of the annual plan

Particularly when dealing with experienced athletes, annual goal setting and aim concretization frequently seem superfluous. Even a brief analysis will show, however, that they are important. Goal setting for annual preparation demonstrates the coach's responsibility and stimulates athletes to undertake serious obligations. Concrete training aims indicate which gains in technique, motor fitness, mental toughness etc. should be striven for in order to attain the main goal. Athletes' motivation and confidence will be higher and more stable when they can clearly see the ways in which the annual preparation can be rationalized (the use of new training methods, enhanced monitoring, employment of new equipment etc.). And finally, coach and athlete should discover the athlete's hidden reserves, which when liberated, will facilitate better performance (Table 7.1).

Table 7.1.
The content and sequencing of goal setting in the annual cycle planning

Items	Content	Comments
Goal	The desired and expected main outcome of annual preparation should be set	The goal should be realistic and formulated concretely (rank, result, position in team etc.)
Aims	The aims refer to essential components of athletic preparedness and propose ways of discerning gains in athletes' abilities	The aims can be expressed as gains in technical, physical, tactical and mental preparedness
Basic directions	The basic directions of how to improve preparation can be specially pinpointed.	The marked directions can concern training methods, organization, equipment etc.
Available reserves	Hidden reserves can usually be found from analysis of preparation and performances	It is necessary to convince the athletes that the noted reserves should be actualized

Unfortunately not every season ends successfully; in this case the coach starts planning for next year by analyzing the failures that occurred. The simplest way of conducting such an analysis is by seeking the external fatal factors affecting the athletes' performance. The array of possible fatal reasons is large: bad draw, low judgment, sudden wind or rain, earthquake etc. Another tactic was employed by one great coach, who was always able to explain to unsuccessful athletes that the training program was excellent and that they (the athletes) were completely responsible for the failure. Still, the correct approach to analysis presupposes the mutual responsibility of both coach and athlete for successful and unsuccessful seasons. This is an important condition for athletes to develop a confident attitude in goal setting for the next season.

7.1.2 Compilation of annual programs

All coaches compile annual programs based on their own experience, knowledge and common sense. However, the Block Periodization approach implies specific demands to planning that can be described by sequencing certain steps (Table 7.2).

Table 7.2.
Step sequence in compiling an annual training program

No	Steps	Comments
1	Determining the target and mandatory competitions	Usually these events are taken from international/national and/or regional calendars
2	Determination of terms and duration of training stages and periods	The stages are determined in terms of target competitions and methodic concept
3	Division of training stages into several meso- and microcycles	Mesocycle directions and durations should be specified
4	Planning of additional competitions and trials	The competitions and trials are necessary to finalize training stages and diversify the preparation program
5	Planning of training camps	Aims, terms and places of camps should be specified
6	Planning of medical and sport-specific examinations	The initial medical exam is planned for early season
7	Calculation of integrative workload characteristics per month	These characteristics can relate to total mileage, number of lifts, throws etc.
8	Calculation of integrative workload characteristics for the annual cycle	Comparison with previous years helps to reveal "weak" points of the plan
9	Correction of plan following revelation of "weak" points	As a rule the first version needs correction and this operation is obligatory

As can be seen in Table 7.2, the initial step requires determination of the most important competitions (Figure 7.1). These events determine the division of the season into stages and periods; the optimal design presupposes planning peak-performance for the ending phase of the training stage (see example in Figure 7.2). The subdivision of the annual cycle into periods follows general logic and is less important than in traditional periodization.

Insert Figure 7.1 about here

Insert Figure 7.2 about here

The next two steps contain a division of training stages into several meso- and microcycles, and the scheduling of additional competitions, which are also planned for early- and mid-season (Figure 7.3).

Insert Figure 7.3 about here

The 5th step prescribes the planning of training camps to better realize the specific objectives of certain blocks-mesocycles. This also relates to the use of altitude preparation (see chapter 9).

Insert Figure 7.4 about here

The next step in annual planning is the calculation of integrative monthly workload characteristics. Such parameters as total number of workouts, total mileage, number of fights and matches, number of quasi-competitive performances etc. can be successfully planned per month. The summation of all monthly characteristics yields the integrative annual workloads, which can be compared with previous years and the data of other athletes. Usually this whole planning process does not lead to the final version of annual program. It must first be reviewed by the administration, colleagues and athletes and repeated analysis will lead to corrections of specific details such as the timing and duration of training camps, cancellation of several competitions etc**.** The corrected program receives the status of the final version that is proposed for realization.

7.1.3 General trends in workload planning within the annual cycle of preparation

The general tendency in annual planning is to reserve the most specialized and rigorous workloads for the training period preceding the most important competition. The Block Periodization approach with its multi-peak preparation does not contradict this position although it exploits it in its own way.

Despite the variety of training conditions and specificity of different sports several common trends in program compilation can be outlined (Table 7.3).

Table 7.3.
Seasonal trends in training program compilation within the annual cycle

Characteristics	Early season	Mid season	Late season
Dominant training methods in accumulation mesocycle	Continuous uniform and alternating exercises	Continuous and slow interval exercises	Strictly programmed interval exercises
Dominant training methods in transmutation mesocycle	Continuous alternating and interval training	Mostly interval exercises	Strictly programmed interval exercises
Diversity of fitness program	Wide range of fitness exercises	A bit restricted range of exercises	Mostly specialized selected exercises
Organization forms of workouts	Higher contribution of individual workouts	Lower contribution of individual workouts	Use of strictly programmed workouts
Use of restoration	Mostly exercising	Higher contribution	Employment of the

means	routine: stretching, relaxation, low intensity aerobics etc.	of physiotherapy, massage, mental training, nutritional supplements	most effective individually selected restoration means
Use of competitive simulation forms	Periodically, not frequently	Systematically, more frequently	Higher contribution in training program

The general tendency in seasonal trends is to gradually increase workload specialization and mobilization of hidden reserves towards the target competition. The general rule postulated by Block Periodization declares that training stages within the annual cycle should be similar but not identical. The stages of mid season and particularly in late season should be more rigorous, more strictly programmed and better managed. It is highly desirable that the most effective training and restoration means and drill combinations be reserved for the crucial periods of annual preparation. Physiologically, this gives the benefit of higher training responses prior to the most important events; psychologically, it heightens athletes' self-confidence, as they know that they have additional reserves during the most stressful phase of their preparation.

Special mention should be made with regard to the competition component of annual preparation. Block Periodization postulates the high importance of competitions even in the early phase of the annual cycle for the following reasons:

1) the competition completes each training stage and is a compulsory component of the training program;
2) the competition breaks routine and inserts a very important element of athletic spirit;
3) the competition provides athletes with extraordinary training stimuli that can not be obtained from regular workloads.

It is worth noting that the competition program varies during the season. It is good to diversify the competition program in early season; to bring the competition program to event-specific standards in mid season; and to adhere to event-specific standards in late season. The reasons for such regulation are obvious. On the one hand, competitions are a compulsory component of the annual program in early-, mid- and late season; on the other hand, a varied competition program helps to diversify the training routine and restore athletes after the habitual event-specific format.

7.2 Quadrennial cycle of athletic preparation

Completion of the Olympic quadrennial cycle is usually followed by serious and detailed analysis of Olympic performances, successes and failures. It is natural for great successes to elicit enthusiasm and inspiration and for failures to cause dissatisfaction, criticism and a tendency to reform. Irrespective of sport-specificity and nationality, the challenge of post-Olympic analysis is to internalize positive experiences and reveal the reasons for sub-par performances. Based on the findings, a new preparation plan is elaborated. It is good when clear and concrete general objectives are determined for each stage of the quadrennial plan. The example of objective setting can be found in the preparation of one of the most successful artistic gymnastics team of Russia (Arkajev & Suchilin, 2004).

Example. The quadrennial cycle of the Russian artistic gymnastics national team is subdivided into eight half-year stages, where each is managed according to a specific proper general objective:

1. Enhancement of sport-specific motor fitness
2. Acquisition of new high complexity technical skills and hybrids
3. Updating of competition combinations
4. Further increase of sport-specific motor fitness
5. Enhancement of technical mastery and attaining stable performances
6. Increase of performance quality, stability and stress tolerance
7. Final compilation of competition combinations; acquisition of sufficient endurance for an entire tournament program; selection of double Olympic squad
8. Modeling of expected competition conditions; attaining high competitive reliability; final selection of Olympic National team.

Each of the above stages encompasses a complex evaluation of the cumulative training effect induced by the completed program.

The above example demonstrates that dividing the quadrennial cycle into separate stages is a matter of professional competence and depends on sport-specific conditions. Nevertheless, the division of the quadrennial cycle into four annual cycles is the most popular. In general, the main directions of quadrennial preparation, irrespective of sport, are presented in Table 7.4.

Table 7.4
Particularities of athletic preparation within a quadrennial cycle

Year	Main directions of preparation
1st	Engagement and examination of new candidates; selection of coaches and other staff specialists; refreshment and correction of habitual training forms and methods, renovation of training repertory; formation of team spirit and partnership between athletes and staff.
2nd	Further selection and approval of new candidates; acquisition of new techno-tactical skills, increase of training workloads, enhancement of training quality
3rd	Obtaining maximal level of training workloads; approval of the annual cycle model planned for the Olympic season; determination of all individual performance characteristics for each team member
4th	Stabilization of team make-up usually at the level of double Olympic squad; stabilization of workloads at the level of the preceding year, approval and stabilization of the model of competitive behavior and performance

Let's consider the above directions with special respect to training designed for athletes of different ages and experience. Highly experienced top-level athletes draw special attention during Olympic preparation both on national teams of leading sports countries, where coaches enjoy a large number of potential candidates, and on relatively small national teams, where the possibility of adding successful new team-members is very limited. The advantages of aged and experienced athletes are obvious: they have a remarkable advantage in terms of basic and sport-specific knowledge, emotional control, stability of technical, techno-tactical skills and competitive behavior. They are usually high-authority persons who positively affect social climate and team spirit. The disadvantages of such athletes are also clear: they are approaching their biological limits of training responses, i.e., they have lesser reactivity to training stimuli; they usually follow habitual training programs and do not like to change their own training style and repertory. Aged athletes perform at a lesser training volume (see 7.3) and need longer transition periods for physical and mental rehabilitation. In the first annual cycle of the quadrennial plan this category of athletes executes substantially less total volume of exercises – about 15-20% less – than in the previous Olympic year (Figure 7.5).

Insert Figure 7.5 about here

Experienced more aged athletes continue the quadrennial cycle with a gradual increase in training volume, which in any case is usually less than for their younger counterparts. The model for the third annual cycle is based on the Olympic year for each category of athletes; thus both aged and younger athletes increase the level of their training workloads and approach their maximum. Generally speaking, the third and fourth annual cycles should be very similar; coaches simulate annual pre-Olympic training design one year before in order to provide the highest preparation quality in the end stage of the quadrennial cycle. In fact the training workload level in the pre-Olympic season is usually higher than one year before for various reasons: higher motivation, better conditions for training and restoration, higher budget etc.

Younger athletes, who have still not participated in Olympic Games have typical characteristics. After attending Olympic preparations their athletic motivation is greatly stimulated and usually enjoy better training conditions: more training camps, more qualified training partners, sometimes more experienced coaches etc. As a result these athletes substantially increase their training workloads as compared with the previous year. In the second and third annual cycles the training workloads continue to rise although at a smaller rate of increase.

From the methodic point of view it is important to predict and plan development of the most relevant motor, technical and tactical abilities. For this purpose it is possible to elaborate corresponding modeling characteristics of these components of preparedness with respect to planned improvement rates during the quadrennial cycle (see Chapter 8).

7.3 Sport longevity of highly qualified athletes

Contemporary sport offers many examples of highly successful athletes who continue their careers up to and even past age thirty. This athletic longevity has been affected by many factors, such as high and stable motivation, proper style of behavior, improved training methodology, social support, financial stimulation etc. As concerns the training itself, a number of age-related particularities can be pinpointed irrespective of the sport involved (Table 7.5).

Table 7.5
Preparation particularities for aged and experienced high-performance athletes as compared with younger counterparts

Factor	Particularities	Comments
Annual cycle structure	Longer duration of transition period	Aged athletes need additional time for psychological and medical rehabilitation

Total training volume	10-30% less than for younger athletes	Aged athletes train more consciously and produce longer training residuals
Organization forms	Higher contribution of individual forms	Aged athletes need less supervision, show more initiative and independence
Restoration process	Increased employment of restoration means	Aged athletes restore slower and often suffer from previous injuries
Equipment	More insistent and creative selection and approval of equipment	Aged athletes have their own demands about equipment; they are serious and consistent during its examination
Individual progress	Motor potential doesn't increase but can be utilized more effectively	Stabilization and reduction of several functions are compensated for by higher efficiency of athletic activity

Of course, a number of additional social factors affect the preparation and behavior of aged athletes. Very often they combine their athletic preparation with professional activity; some aged athletes have their own families and this substantially changes their mentality and life priorities. However this book is about training; let's illustrate the above preparation particularities through the examples of two outstanding athletes who attained magnificent results during their long athletic careers.

Case study of long-term trend of training workloads. The world-famous canoeist, Olympic Champion Ivan Klementiev represented the USSR and from 1991 Latvia during four Olympic cycles. He earned one gold and two silver Olympic medals and seven gold World Championship medal. During a period of 19 years many training characteristics of his athletic preparation were well documented, the most integrative of them being total annual paddling volume (Figure 7.6). Analysis of multi-year dynamics of annual training volumes reveals a number of salient tendencies:

- Maximal training volume was attained at age 21 when the athlete trained with the USSR national squad; afterwards annual training volumes tend to decrease despite periodic deviations;
- Quantitative analysis of average annual volumes over quadrennial cycles where the athlete took part in Olympic Games reveals the following trend: age 21-24 – 100%; age 25-28 -88.2%; age 29-32 – 77.4%, and age 33-36 – 61%;
- Analysis of periodic oscillations reveals a remarkable increase of training volumes in the final years of an Olympic cycle; one exception, in 1984, can be explained by political but not methodic circumstances – instead of the Los Angeles Olympics that was held in August the athlete competed in a substitute regatta of socialist countries held in July; thus the season became one month shorter;
- Reduction of annual training volume is partly conditioned by longer transition periods, whose duration increased from one to three months during the athlete's career.

Insert Figure 7.6 about here

It should be emphasized that despite the constant decrease in total workloads, Ivan Klementiev continued to give extremely successful performances and after age

30 won four gold medals at World Championships and two Olympic silver medals. Apparently, workload reduction was effectively compensated for by higher quality of training. This training enhancement was associated with more better preparation planning exploiting the ideas of Block Periodization, a more conscious and proper selection of exercises and avoidance of non-compatible workload combinations, constant attention to restoration, and the use of a logical competition program (Klementiev, 1994). This great athlete also utilized his valuable experience in other activities; Mr. Klementiev has been a highly successful coach, serving on the national canoe squads of Poland and Spain and he also earned a Ph.D. degree.

As was already stated, long-term preparation is characterized by a cumulative training effect, in which physiological evaluations are of special interest. Unfortunately, such data for multi-year training among elite athletes are very limited. Therefore, the case study of the legendary cyclist Lance Armstrong is unique and extremely interesting (Coyle, 2005).

Case study of physiological changes during long-term preparation. Lance Armstrong, world famous bicycle racer, became World Champion and seven-fold Grand Champion of the Tour de France, the most famous and prestigious road race in the world. From age 21 to 28 he was examined in a physiological laboratory for body composition, maximal oxygen uptake, maximal blood lactate and mechanical efficiency of pedaling. At age 24 he was diagnosed with testicular cancer and during a two year period he came through brain surgery and treatment that included chemotherapy. From age 27-32 Lance Armstrong was victorious six times in the Tour de France, an indubitably incredible success in world sport.

During a seven year period, from age 21, the athlete's body weight slightly increased by 0.8 kg while lean body weight increased by 1.1 kg. The multi-year trend of physiological variables displays the following particularities (Figure 7.7):

- the maximal oxygen uptake reached peak value at 23 yr, declined after medical treatment and did not reach the highest level at age 28 when he won the Tour de France;
- maximal heart rate decreased by 6 beat/min;
- mechanical efficiency as the ratio of mechanical work to energy expended in this time interval, increased by 8.8%;
- mechanical power obtained at oxygen uptake of 5.0 l/min displayed a substantial increase of 18%.

It is worth noting that the final estimate of maximal oxygen uptake, 71 ml/kg/min, is inferior to the data of elite cyclists which approaches a level of 80 ml/kg/min (Padilla et al., 2000). It can be speculated that when Lance reduced his body weight prior to the races, the real level of maximal oxygen uptake per body weight became higher than previously. Nevertheless the study findings indicate that the individual progress of the great athlete was determined not by enlargement of his physiological potential but by its more efficient utilization. The physiological mechanism of this improved muscular efficiency is still unclear. The hypothetical contributors to such improvement can be associated with pronounced hypertrophy and improved contractility of slow muscle fibers; alteration in myosin ATPase activity, increased cycling efficiency induced by altitude training and enhanced pedaling technique.

Insert Figure 7.7 about here

It should be noted that Lance Armstrong attained enormous sport success after extremely serious surgery and medical treatment; his autobiography gives an example of magnificent athletic and human fortitude (Armstrong, 2000). Of course, his athletic career and individual data are unique. Nevertheless the tendencies revealed in the case study of Armstrong's progress are highly typical. Indeed, many highly qualified athletes approach their biological limits but continue to attain best performances and even improve their athletic results. Usually the main source of such individual progress is better utilization of their motor and physiological capabilities. This improved utilization can be conditioned by physiological, biomechanical and psychological factors, where individual creativity, self-confidence and athletic wisdom play an immense role.

7.4 Long-term preparation of young athletes

The athletic career of both world-class stars and less successful sportsmen is highly dependent on the earlier period of long-term preparation that usually begins in childhood. The purview of this chapter restricts consideration of this matter, which is worthy of a book of its own. Nevertheless, the most relevant and generalized aspects of young athletes' long-term preparation will be presented below, namely: the content and sequencing of different stages, the concept of sensitive periods in long-term preparation, and the basics of identifying gifted youngsters.

7.4.1 Stages and details of long-term preparation

The common approach to long-term preparation for athletes assumes that four separate stages can be distinguished, to facilitate proper duration and yearly training characteristics (Table 7.6).

Table 7.6.
Stages of long-term preparation and their general characteristics (based on Issurin, 1994)

Stages	Duration in years	Workouts: number per week	Workouts: duration in min	Yearly training volume: hours
Preliminary preparation	1-3	3-4	45-60	120-170
Initial specialization	2-3	4-5	75-90	250-300
Advanced specialization	2-3	6-9	60-120	500-750
Sporting perfection	i.d.*	6-12	70-150	750-1400

* individually dependent

Let us consider the separate stages of long-term preparation for athletes. The initial stage of preliminary preparation varies from one to three years depending on sport-specific demands and the age at which athletes begin systematic training. Apparently the favorable ages for starting vary widely in various sports (Figure 7.8).

Insert Figure 7.8 about here

The common tendency in contemporary sport is a reduction in age for children to prepare for specific sports. Various reasons explain this trend, such as the availability of high quality equipment designed for children (barbells, boats, paddles etc.), enhanced training conditions, popularization of sport activities for children by the media, and examples of world-known stars who started their sport preparation very early. This reduction in the starting age of competition has greatly affected the international and national sport organizations. For instance, a few decades ago it was generally agreed that boys should begin weightlifting training no younger than age 14. Now the general practice worldwide is for schoolboys to take part in international weightlifting competitions at age 11 and even earlier. Of course, sport-specific demands strongly affect when newcomers can begin and the duration of their preliminary preparation. For example, many juniors start systematic triathlon training with serious previous experience in swimming. Thus, the duration of their preliminary preparation depends on how long it will take them to acquire cycling and running skills, and can last about one year. Therefore, the data presented in Figure 7.8 reflect worldwide practice but does not include special situations in which youngsters begin their training earlier or later.

The initial stage, "preliminary preparation", is characterized first of all by multilateral, attractive and not excessive workloads where harmony between basic technical and fitness exercises is of particular importance (Table 7.7). It is generally agreed that children with higher level motor abilities have visible benefits in acquiring new sport-specific skills. On the other hand, children with lower initial fitness levels may possess high sensitivity to training stimuli and within a given time may equal or even surpass the leaders. Therefore, a period of about one-two years of preliminary preparation is needed both to strengthen interest, motivation and willingness to continue training in a selected sport, and to evaluate the predisposition and inborn gifts of newcomers for a specific sport. Participation in competitions is strongly recommended at this stage but in reasonable quantities and using a diversified competition program. The training program as a whole is of great importance for forming and developing proper mental abilities which can decisively determine whether long-term preparation will continue.

Table 7.7.
Main training directions in the preliminary stage of preparing athletes

Abilities	Main training directions
Technical	Acquisition of sport-specific and general skills, development of specific and general coordinative abilities
Physical	Multilateral development of all motor abilities with special respect to sport-specific demands, increase of general training capacity
Tactical	Acquaintance with tactical demands of selected sport, acquisition of basic tactical knowledge and techno-tactical skills
Mental	Consolidation of interest in selected sport; formation of stable motivation and conscious will to continue preparation; adoption of fundamental moral principles of "fair play", team spirit etc.

The second stage of long-term athletic preparation, called initial specialization, is devoted to further development of sport-specific technical skills and motor abilities (Table 7.8). This is the period in which young athletes make their conscious selection of the most appropriate disciplines and events. The program of technical and physical preparation became more specialized; it is important to adapt athletes to the training workloads typical of this sport. Participation in competitions is an indispensable part of the overall preparation; it also provides an opportunity for coaches and athletes to assess levels of tactical and mental abilities, which are an important focus of attention.

Table 7.8.
Main training directions in the initial specialization stage of preparing athletes

Abilities	Main training's directions
Technical	Further development of sport-specific skills and selection of the most favorable sport disciplines and events, further enlargement of technical repertory and coordinative abilities
Physical	More specialized development of motor abilities focusing on sport-specific demands, basic adaptation to training workloads typical of this sport
Tactical	More profound learning of competition rules and tactics, further enhancement of tactical knowledge and techno-tactical skills
Mental	Acquisition of self-confidence and will power; formation of consciousness and responsibility in situations of training routine and competitions; further strengthening of motivation to train and compete in the selected sport

The third stage of long-term preparation, termed "advanced specialization", encompasses the period in which athletes obtain the real basis of mastery. Usually it corresponds to the age at which athletes complete their junior preparation and join the population of adult athletes. Consequently, their technical and physical abilities should approach the level of qualified adults (Table 7.9). Concomitantly, training workloads increase substantially and may approach those of adult athletes. It is worth noting that despite increased technical and motor potential, juniors at this stage are still not completely matured and the use of maximal workloads should be restricted. In particular administration of highly intensive anaerobic glycolitic exercises requires complete control because highly qualified juniors can be overly ambitious in training routine but not experienced enough in self-regulation of metabolic and muscular reactions. Nevertheless, participation in competition is of particular importance at this stage both as a part of the overall preparation program and as indispensable activity for strengthening motivation to sport excellence and the acquisition of extremely useful skills of emotional control and mental regulation. In addition, personal traits such as self-confidence and will power are no less important for successful athletic careers than proper techno-tactical and sport-specific motor potential.

Table 7.9.
Main training directions in the advanced specialization stage

Abilities	Main training directions
Technical	Attaining proper technique in selected disciplines or events; establishing

	individual technical style, elimination of individual technical drawbacks
Physical	Further enhancement of sport-specific motor abilities, formation of sufficient motor potential for proper and individualized movement technique
Tactical	Formation of individual tactical and techno-tactical style, improvement of techno-tactical coordination
Mental	Formation of motivation to attain sport excellence, enhancement of emotional control, acquisition of mental regulation skills, maintenance of high self-confidence and will power

The fourth stage of long-term preparation, if an athlete achieves it, is the most variable in duration. For world-class stars such as Ivan Klementiev and Lance Armstrong (mentioned above) this stage lasted almost twenty years; for the majority of high-performance athletes it encompasses four-seven years, during which they enhance their preparedness and compete with maximal sport ambitions. This stage is definitely the period of highest individual creativity, when experienced athletes can consciously contribute to their programs in terms of movement technique, motor fitness, tactics and strategy, and mental training (Table 7.10). Of course, the improvement rate of motor and technical abilities is much lower at this stage than previously. As was mentioned in Table 7.5, the motor potential of aged experienced athletes is enhanced mostly through better utilization.

Table 7.10.
Main training directions in the sporting perfection stage

Abilities	Main training directions
Technical	Further enhancement of movement technique with special regard for individual style and particularities of the athlete
Physical	Attaining the highest level of sport-specific motor abilities and their improved utilization in a properly selected individual manner
Tactical	Attaining tactical creativity, further enlargement of techno-tactical repertory, perfection and automatization of favorite techno-tactical skills
Mental	Total commitment to excellence, attaining the highest level of self-confidence, self-regulation of arousal , effective emotional control and mental toughness

It is commonly agreed that outstanding athletes are usually striking and brilliant personalities. The individual traits of outstanding athletes have been subjected to thorough investigation.

Studies. Gould and others (2002) interviewed 10 Olympic champions and persons who knew them very well: parents, coaches, colleagues. It was found that each outstanding athlete had the following personal features: high level of confidence, optimism, adaptive perfectionism, sport intelligence and mental toughness. They had also abilities to cope with anxiety and control it, to set and achieve real goals. The comparison of medal winning Olympians with less successful participants of Olympic Games revealed additional important factors of sport excellence: ability to react positively to unexpected events and numerous distractions, adherence to performance routines, team unity and cohesion, support of family and friends (Gould & Carson, 2007).

In conclusion it is worth noting that personal traits like confidence, optimism and sport intelligence, and factors like social support, which contribute to Olympians' success, are also relevant for athletes' preparation in the earlier stages, although to a lesser extent.

7.4.2 Sensitive periods in the development of different motor abilities

Both researchers and practitioners have remarked that during certain periods in individuals' lives they are more trainable for certain motor abilities than in other times. These time intervals have been termed "sensitive periods" and are based on the following physiological facts:

a) The natural development of physical (motor) abilities and physiological functions in children and youths is non-uniform; the sensitive periods make it possible to gain more pronounced progress and the most favorable rate of improvement in certain abilities;
b) The periods of acceleration and deceleration of motor development for different abilities do not coincide chronologically; some of them "jump" earlier, the other ones – later.

Non-uniformity and chronological heterogeneity in the development of various motor abilities are widely known phenomena. However, chronological determination of the sensitive periods with regard to specific motor abilities remains open to dispute. Indeed, each fitness component can be characterized by various indices, which can give different (and at times contradictory) chronological trends. This explains the variance in data from different sources. Another approach entails comparing training-induced effects achieved at different ages. Using this approach, the sensitive periods were determined and are displayed in Figure 7.9.

In general, the sensitive periods are determined by growth, maturation and natural trends in the development of the movement system. Physical activity and in particular specially organized training is a conspicuous integrative factor, which stimulates and augments the natural physical trend. For instance, the most favorable period for improvement of general motor coordination is between ages 9-12 years. To be sure, coordinative ability increases at an older age as well, but its improvement rate is lower. Similarly, flexibility increases considerably more at age 7-10 years when the high elasticity of tendons, ligaments and joints is the beneficial factor aiding progress. The elementary forms of speed also develop non-uniformly; the highest improvement rate for maximal movement frequency occurs at age 11-13 in both girls and boys; reaction time improves particularly at 9-11 years.

Insert Figure 7.9 about here

The influence of growth and maturation is especially pronounced with regard to the strength abilities. Achievements in high- and long jumps depend on muscular contractive potential and body mass. The latter component increases most remarkably in mid-puberty girls aged 13-15; therefore, their maximal improvement rate occurs at 11-13.

Boys benefit from enhanced high- and long jump in the period of ages 13-17. The improvement in maximal strength attained in mid-puberty and late-puberty is directly affected by hormonal changes (maturation) and an increase in muscle mass (growth). It is well known that improvement in muscle strength is a result of better neural regulation as well as muscular hypertrophy. It is worth noting that training-induced hypertrophy is much more pronounced in adults compared to mid-pubertal or late-pubertal children. Therefore, improvement in neural regulation is the main source of increased explosive and maximal strength. Neural adaptation improvement also contributes to gains in strength endurance. Other contributors relate to metabolic factors (aerobic and anaerobic energy supply) and hormonal aspects. More specifically, the androgenic hormones (e.g., testosterone) affect anaerobic power generation and muscle hypertrophy; their concentration is much lower in children and starts to increase at 12-13 in girls, and 13-14 in boys.

Advanced practice has been shown to have considerable effect in aerobic training for children ages 9-12, however the most favorable periods for aerobic endurance enhancement appear in mid-pubertal children, from age 14 in girls and 15 in boys. The most influential factors affecting this sensitivity are increased body size and particularly muscle mass, increased heart volume, total blood volume, and higher hemoglobin concentration.

The sensitive periods are actively exploited in training systems with young athletes although commensurate pedagogical precautions are necessary. The higher sensitivity of children and youth can lead to overload and even injury. This is particularly relevant in planning maximal strength and power exercises.

7.4.3 Identifying gifted athletes

In general giftedness can be characterized as a predisposition to and higher trainability for a given activity, which are considered to be genetically transmitted properties of an individual. In sports, properly developing this gift implies attaining sport excellence. Apparently, the earlier this giftedness is identified, the more effectively the individual's athletic preparation can be managed and the greater is the probability of developing an elite athlete. Thus, a gifted child is potentially a talented athlete and, therefore, identification of giftedness can be based on unchangeable inherited predictors of talent. According to the current approach (Williams & Franks, 1998; Williams & Reilly, 2000), sport talent is determined by four generalized factors: anthropometric, physiological, psychological and sociological. Each of them contains numerous characteristics that can serve as predictors of potential talent. Some anthropometric and physiological variables are highly dependent on heredity (see Tables 3.2 and 3.3) and as such, can not be compensated for by other personal traits. Thus, they can restrict progress in a given sports. Several psychological personality traits are somewhat inherited (Plomin et al., 1994; Saudino, 1997) and therefore can be altered during preparation. Sociological conditions are not heredity-dependent; this doesn't mean, however, that they can be changed easily if necessary (Table 7.11).

Table 7.11.

Factors determining athletic talent, its characteristics and their dependence on heredity

Factors	Characteristics *	Genetic determination*
Body build and body composition	Body lengths: height, extremities, foot	strong
	Body breadths: shoulders, thigh etc.; muscle mass	medium
	Total body fat	low
Physiological	Alactic Anaerobic Power Peak blood lactate Space orientation	high
	Glycolitic Anaerobic Power Strength endurance (resistance to acidity) Flexibility	medium
Psychological	Self-confidence Anxiety control Motivation Concentration	medium-low
Sociological	Parental support Socio-economic background Cultural background Coach-child interaction	heredity independent

* - see also Tables 3.2 – 3.4.

The identification of gifted, that is, potentially talented athletes can be based, first, on unchangeable predictors, most often associated with anthropometric and physiological factors. This approach led to the development of a practical "tool", the so-called modeling characteristics, which describe favorable combinations of anthropometric and physiological estimates for different age categories (Bulgakova, 1986). The characteristics were used for identifying the candidates with the most prospects for benefiting from more specialized training. The main limitation of this evaluation lies in the differing levels of maturity of children that are examined and assessed during gift detection. Children with slower rates of maturation may be found inferior to more matured teammates but may nevertheless have greater potential for further progress.

Special mention should be made about determining the most favorable combinations of anthropometric and physiological estimates for different ages. Such age related models can be created through prospective longitudinal investigation of large group of athletes, where one sub-group attains the elite level. Data for the athletes registered in the different periods can be used as modeling characteristics for corresponding age categories. It is obvious that such a study, which would have to take a number of years, looks difficult and problematic organizationally, but such long-term research projects have been conducted (Vorontsov et al. 1999; Falk et al., 2003). Much more common are so-called cross-sectional studies that compare less successful and more successful youngsters and whose results are used to reveal specifics about hypothetically gifted athletes.

Case study and example. 320 swimmers aged 11-18 years participated in the USA Select Program and were examined with respect to biological age, anthropometric status, muscle strength and power, swim-specific abilities and performance time. The results highlighted that the best athletes at younger ages are usually more mature than less successful counterparts while the favorites at older ages are mostly on-time maturers (80% of the US National team) or late maturers (18% of the team). The authors suggest that high performing late maturers have better chances of remaining involved with the sport for longer periods (Troup et al., 1991)

Another approach to considering the problem is through retrospective studies, in which the development of outstanding athletes is carefully analyzed with respect to performance trend, changes of body size etc. The number of available characteristics for retrospective analysis is usually limited but the benefits of such studies are obvious – this is only way to reconstruct the unique athletic progress of Olympic and world champions from their childhood to the podium.

Case study. 35 world leading canoe-kayak paddlers who took part in USSR National team and earned medals in the Olympic Games and world championships within eight years prior the study, were interviewed with respect to their official performance results from ages 14-15 yrs, corresponding to the end of their first year of long-term preparation (respondents who began their preparation later were excluded from the analysis). The collected data were subjected to statistical analysis and the average performance trends of elite paddlers were calculated (Figure 7.10). Despite the substantial improvement of paddles and boats in the two decades since this study was conducted, the results achieved by outstanding athletes in the earlier stages of their preparation remain relevant to this day for the evaluation of giftedness in today's young athletes (Sozin, 1986).

Insert Figure 7.10 about here

In recent decades many research projects have been conducted in order to develop multidimensional models of gifted athletes in different sports. Such models encompass many characteristics of body build, motor fitness etc. and make it possible to compare real children with “virtual candidates for future excellence” in a given sport (see, for instance, the publication of Arnot & Gaines, 1986, and Brown, 2001, where such data can be found).

Another general approach can be recommended to a coach in any of several sports as a part of the initial preparation of youngsters. This approach is based on the assumption that giftedness is comprised of two major components: a predisposition to certain sport activity and trainability to corresponding workloads (Figure 7.11). Furthermore, these components determine the effect of initial preparation: a predisposition to certain sport affects the *initial level* of relevant motor fitness (speed, endurance, agility etc.), while trainability, the second component, determines the *improvement rate* of development during initial preparation. This assumption has several restrictions: predisposition to a certain sport is not the only determinant of motor fitness level that can be examined; previous experience in this activity (preliminary training, acquaintance with tests etc.) also has a strong effect on the outcome of initial examinations.

Insert Figure 7.11 about here

Example. Imagine examining the swimming fitness of a group of eight year old children. A few members of the group already have some aquatic experience (practice with parents or older relatives, games in shallow water etc.); others have a few learning episodes and are more or less accustomed to movement in water; the rest have no experience at all. Evidently, the behavior of these children in water will be very different and previous experience will affect the results much more strongly than the children's real predisposition to competitive swimming.

The second restriction relates to the improvement rate during initial preparation, which depends not only on an individual's trainability but also on quality of the preparation. This restriction is relevant when comparing the progress of athletes who train under different conditions with different coaches. However, for athletes training in one group with the same coach, the improvement rate of results adequately reflects trainability.

Basing on this so-called "dual approach" to giftedness, identification is comprised of evaluating the initial level of sport-specific fitness and its improvement rate during initial preparation. This diagnostic was firstly implemented in ball games mostly for practical needs (Bril, 1980). The general logic of the dual approach is presented in Figure 7.12.

Insert Figure 7.12 about here

One more remark must be made concerning the optimal duration of preparation necessary to evaluate improvement rate, i.e., the trainability of young athletes. There is no simple unequivocal answer for this question and the following circumstances can be considered regarding this concern:

1) The absolute unsuitability of certain individuals for specific sports can be recognized quickly (tall and heavy candidates in artistic gymnastics; small children in basketball etc.);
2) Absolutely ungifted candidates can usually be recognized during a relatively short-term preliminary preparation lasting about three-four months;
3) Diagnosing giftedness in maximal speed and power sports needs a relatively short period and usually lasts up to one year;
4) Identification of gifted children in highly coordinative sports (artistic gymnastics, figure skating etc.) is strongly restricted by the terms of initial preparation, which is usually earlier than in other sports (Figure 7.8); the evaluation process takes between 1-2 years;
5) In ball games, where children start systematic preparation relatively later (Figure 7.8), very gifted candidates can be identified relatively faster (two-three months) but usually this process demands about one year;

6) Perhaps the longest period for giftedness identification is necessary in endurance sports, where many world-level sportsmen were recognized as potential elite athletes after three-four years of systematic preparation.

> **Evidence of genetics**. Based on the outcomes of studies with young adult twins, it has been found that the contribution of heredity related factors to training response in an endurance program is different for earlier and later stages of preparation. The initial preparation is less dependent on heredity; however, as athletes progress and approach higher workloads, the genetic control of their training response becomes much stronger (Bouchard et al., 2000). This characteristic of training responses partly explains why several gifted endurance athletes can not be effectively recognized at the earlier stage of their preparation.

The final remark relates to the genetic component of athletic giftedness. Of course, its importance can not be underestimated. Viewed from this angle, a coach's interest in family athletic history and the achievements of the older relatives of a newcomer is both reasonable and desirable. Only a few outstanding athletes had great champions among their parents (Table 3.1), but most of them were born and grew up in families with physically active and sport oriented persons.

Summary

Long-term athletic preparation has been considered with respect to designing relatively prolonged training cycles (annual and quadrennial), multi-year preparation of adults, and multi-year preparation of young athletes. The basics of annual cycle compilation include: goal and aim setting, sequencing the main steps in annual plan design, and general tendencies in workload compilation. All these items are considered in light of the Block Periodization concept. Special attention was given to seasonal trends in training workloads within the annual cycle of preparation (Table 7.3). Particularities of quadrennial planning were given with regard to preparing highly qualified athletes. Special attention was given to workload trend in preparing aged experienced athletes and their younger counterparts. The problem of athletic longevity was briefly analyzed with respect to the characteristics of more aged and experienced athletes (Table 7.5). The typical trend of annual training workloads were presented together with a case study of many-time world and Olympic canoeing champion Ivan Klementiev (Latvia), while physiological changes during long-term preparation were considered on the basis of a case study of world champion and seven-time Tour de France champion Lance Armstrong (USA). It was proposed that many aged athletes approach their biological limits but continue to attain outstanding performances, and even improve their athletic results. The source of such individual progress can be attributed to better utilization of their motor and physiological capabilities, where individual creativity, self-confidence and athletic wisdom play an immense role.

The common approach to long-term athletic preparation presupposes the distinguishing of four separate stages: preliminary preparation, initial specialization, advanced specialization, and sporting perfection. Each of them is characterized by the proper combination of stage length, frequency and duration of workouts, yearly training volume and other sport-specific variables. The physical, technical, tactical and mental particularities of each stage were summarized and considered in general (Tables 7.7-7.10).

In terms of biological maturation, the concept of sensitive periods is of special importance. According to this concept there are the periods in individuals' lives when young athletes are more trainable for certain motor ability than at other times. Consequently, the periods of more favorable training responses can be exploited for more conscious and beneficial development (Figure 7.9). Special attention was drawn to the identification of gifted young athletes, because earlier identification of giftedness permits more effective management of preparation in potentially talented athletes. Prospective and retrospective approaches for determining valid and informative indicators of giftedness were considered. For practical ends and general evaluation of giftedness, it is highly recommended to evaluate the initial level of sport-specific fitness as characteristics of a predisposition to a given sport, and the improvement rate of athletic abilities during initial preparation as an indicator of trainability. The comprehensive scheme (presented in Figure 7.12) makes it possible to estimate athletic giftedness in general.

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Chapter 8. Modeling in planning, evaluating and guiding training

Almost four decades ago a young sport scientist from Moscow, Vladimir Zatsiorsky, published the book "Cybernetics, Mathematics, Sport" that introduced new ideas for training control and elucidated their practical implementation (Zatsiorsky, 1969). Since that time modeling as a term and concept has been adopted in the theory of sport training and has successfully served many practical needs. At present modeling is generally understood as the way and method of simulating an athlete's state, athletic performance and training process using formalized descriptions, logistic schemes, computer programs and even proper practical tasks. The intention of this chapter is to present and consider the most comprehensive and practical modeling approaches in use, to help enhance the preparation of athletes.

8.1 Generalized model of athletes' preparation

The entire process of preparing athletes over a given time span can be presented as a simplified three-level model (Figure 8.1).

Insert Figure 8.1 about here

This three-level model can be compiled and specified for specific sub-groups of athletes of similar preparedness, for instance, a national team of middle-distance runners. Another application can be the compilation of an individual model for a specific athlete taking into account his/her personal particularities and event-specific demands. In both cases the upper level of the model describes top-performance and includes the targeted result (in record sports), detailed characteristics of optimal performance, quantitative model characteristics of tactics, technical variables, and competitive behavior. An individual model should include personal equipment, pre-event warm up, protocol behavior prior to and following performance (cooling down etc.). The medium level of this scheme presents the model of sport-specific abilities necessary to attain the planned (modeled) performance. This level contains quantitative model characteristics of anthropometric status, motor and technical abilities, the attainment of which will ensure the planned performance. The mid-level model also includes mental skills and required knowledge of rules, training methods, competitions’ conditions etc. The bottom level in Figure 8.1 contains a model of training programs that summarizes, first of all, the most relevant characteristics of preparation, i.e., total and partial annual training volumes, number of competitive and quasi-competitive performances, patterns of meso- and microcycles and even single workouts. The programs of active restoration like mental relaxation, nutritional supplements, massage and other recovery means should be also taken into account.

In the mid-1980s the ideas of modeling became very popular among serious coaches. The general logic of the modeling approach can be expressed by the following scheme (Figure 8.2).

Insert Figure 8.2 about here

The “initial state” of an athlete, group or team is evaluated and analyzed with regard to required level, limiting factors and available reserves. The “model” is developed on the basis of this analysis. A so-called “ideal model” may be proposed without specifying concrete terms of realization, but normally the model is oriented towards a given period of preparation, usually for each annual cycle. “Preparation” means realizing the various aspects of the proposed model, where intermediate examinations are used to correct the program following marked deviations. “Evaluation” as the concluding operation serves to compare the state and level of preparedness attained with the proposed model. Realistically, such a comparison may yield one of three possible situations:

1) The attained state completely corresponds to the proposed model. Such a situation is extremely rare and if it is attained, the coach is worthy of compliments and congratulations;
2) The athlete's state corresponds in general to the proposed model but the expected result (rank in competition, medal etc.) is not attained. In this case the model should be revised radically taking new facts and evidence into consideration; correspondingly, the preparatory program should also be corrected;
3) The athlete’s state is inferior to the proposed model. In this case the preparatory program and in particular its implementation should be re-examined critically. Usually appropriate corrections are necessary in both the program and its realization.

8.2 The top-performance model.

The top-performance model can be developed for individual athletes, for a group of athletes of similar level and in the same event or function, and for a team. Obviously, top-performance models differ for individual and team sports. In both cases the model should be predicated on three elements: (a) the real goal of multi-year preparation (world- or national rank, winning a medal, Olympic qualification etc.); (b) the predicted level and performance characteristics, which provide the goal to be attained; (c) the present level and performance characteristics of the individual or team. Let us illustrate the modeling approach through examples in various sports.

8.2.1 Individual sports

It would not be an exaggeration to state that each top-level athlete in individual sports has and executes his/her own athletic performance in accordance with a specific ideal model. However this does not mean these models were consciously formulated and described. Many experienced athletes have a clear virtual image of the ideal performance and feel no necessity to formulate it. Nevertheless, such systematic description is still desirable; at worst it will not impair performance and at best it can be highly useful for mental and physical preparation. The general approach to top-performance modeling is presented in Table 8.1.

Table 8.1
Components and content of a top-performance model: general approach

Component	Content	Comments
Pre-event warm up	Thoroughly prescribed and approved combination of exercises and techno-tactical tasks	Protocol includes approval of personal equipment and available conditions
Behavior between warm up and performance	Strictly prescribed sequence of rest, relaxation and activating procedures, personal tuning	Timing, content and assisting persons should be defined properly
Performance itself	Clear and detailed description of each part of performance including objective indicators	Individual model can also include subjective signals
Cooling down	Clear description of cooling down program and post-event recovery (massage, drink etc.)	This is highly important for athletes facing a number of performances during a given competition

It has already been noted that experienced athletes know their behavior program during the competition very well, but the influence of emotional strain, particularly in highly important tournaments, can not be underestimated. Sometimes, under emotional strain, several details may slip the competitors' attention, something that would not happen in a usual, comfortable situation.

A model of top-performance is definitely of importance by itself. Under normal conditions it can enable athletes to utilize their athletic potential to the maximum. As a general rule – the top-performance model should be as deterministic as possible. Therefore, in sports, where athletes have no immediate interaction with opponents during performance (like swimming, rowing, figure skating etc.), the model can be strictly prescribed. Let us illustrate this with an example of flatwater canoe racing.

Case study. A world-class kayaker was monitored during his long-term preparation for the 2004 Athens Olympics. His top-performance model for 1000m single-kayak was thoroughly designed to attain specific predicted result and was calculated for optimal weather conditions and proper velocities (Table 8.2). The modeled Stroke Rate (SR) pattern was developed based on individual techno-tactical particularities of the athlete (Figure 8.3). Current race patterns were compared with the model. The performance at the 2002 World Championship had excessive SR on the start (the athlete didn’t succeed in generating sufficient stroke power); performance at the Pre-Olympic Athens regatta was closest to the model; performance at the Athens Olympics had excessive SR in the first half and excessive SR decline in the third quarter. The best model realization, the best result and the highest personal rank (gold medal) was attained in the Pre-Olympic regatta. Therefore, the top-performance model was verified in a number of competitions (based on Issurin, 2005a).

Table 8.2
Top-performance model of a world-ranked kayaker for the single-kayak 1000 m event

Performance characteristics	Influencing factors	Modeled values
Performance time; min, s	World trend in results among top-athletes over the last five years; performance potential of R.Y.	3:28.5
Times for 250 m segments, s	Proper mobilization of athlete's physiological and biomechanical capabilities	50.6 52.5 52.8 52.6
Stroke Rate pattern	Individual biomechanical preconditions of power application over the entire distance	138 – 111 strokes/ min (see graph)

Insert Figure 8.3 about here

It should be emphasized that effectiveness of modeling depends directly on two relevant factors: (a) precision and completeness of the proposed performance model; (b) precision and completeness of the competition analysis that makes it possible to estimate how the model was realized.

Example. Since 1994, all semi-final and final races in every top-level swimming competition, such as the World Championship, Olympic Games and European Championships, are videotaped and analyzed with respect to the most meaningful performance characteristics: time of start and turn segments, average speed, Stroke Rate and Stroke Length on each segment of the distance etc. (Haljand, 1997). After the competition the participants receive a full report; using the data of winners they can compile an ideal performance model; comparing their own data with the model they can reveal hidden reserves and direct further preparation.

8.2.2 Team sports

It is apparent that top-performance models in team sports are more complicated and, especially in ball games, less deterministic. Thus, it is a genuine challenge to construct a scenario that can take the unpredictable actions of opponents into account. Nevertheless, the general approach to modeling (Table 8.1) may also be suitable for team sports.

It is worth noting that in team sports, where group and individual interactions are of particular importance, models of pre-event warm-up and proper pre-competitive behavior can contribute greatly to successful performance. The example of a modeled pre-match warm-up in football is presented below (Table 8.3).

Table 8.3

Typical modeled pre-match warm-up for professional and semi-professional football teams (based on Bangsbo, 1994)

Duration, min	Content	Range of HR	Remarks
4-5	Jogging, whole body exercises in moving and standing position; Light stretching exercise series	80-100	Usually performed individually
3-4	Exercises for main muscle groups used in game; 2nd series of stretching exercises	90-110	Can be performed in small groups
4-5	Exercises with ball in pairs: passing, dribbling etc. Light stretching exercise series	110-130	One ball for each two players
4-5	Players play in small groups: four against two; three against three… Light stretching exercise series	130-150	Can be performed with the coach's supervision
4-5	A six-a-side game (6v6) with shooting at the goal	166-190	The most stressful part of warm-up

Similarly modeled warm-up and pre-event behaviors increase performance stability and reduce emotional tension in highly coordinative aesthetic sports. Team performances in aesthetic sports (rhythmic gymnastics, synchronized swimming, figure skating) are characterized by very high complexity and high risk of mistakes. However, unlike ball game performances, these sports are strictly programmed. Therefore, top-performance modeling is a compulsory part of the preparation process in these sports. A general algorithm of top-performance modeling in the aesthetic sports is presented using the example of synchronized swimming (Table 8.4).

Table 8.4.
General algorithm of top-performance modeling in an aesthetic team sport: duet and group events in synchronized swimming (based on Issurin, 2005b)

Sequence of operations	Examples	Remarks
Raising general idea of performance	"Circus", "Carnival in Venice", "Beauty of spring" etc.	General idea determines the style and music
Selection of the style of composition and music	"Romantique", "Classique", "Jazz", "Folklore" etc.	Style and music require appropriate choreography
Determination of Culmination hybrids	"Barracuda" with high level of risk; "Thrust" with non-balanced movements; more than 10 twists on the same level	These hybrids and their complexity will affect athletic level of performance
Determination of individual roles within the group (duet)	Acrobatic stunts, supports and other "roles" should be properly allocated	The earlier allocation of roles for athletes enhances quality of preparation
Compilation of entire top-performance composition	Description of detailed scenario of entire composition	Working on perfecting the model

There can be no doubt that modeling top-performance in ball games is very complicated and problematic. Nevertheless, the possible variants of opponents' tactics are predictable. Therefore, typical situations can be described and adequate tactical models can be compiled and prepared. It is suggested that such modeled techno-tactical training will contribute to successful performance.

8.3 Model of sport-specific abilities

The area of sport-specific abilities is very large and multi-faceted. Describing them scientifically can be very detailed, multi-dimensional and creative. However, the practical approach to the modeling of sport-specific abilities is restricted by the real possibility of employing the measurable and most relevant characteristics that form a battery of valid indicators. It seems that the major contributors to such models are anthropometric status on the one hand, and the physiological and sport-specific characteristics of motor abilities on the other. Other considerations can also be the focus of attention (psychological characteristics are also very important but for these, readers are referred to other books; see Weinberg and Gould, 2003; Blumenstein, Lidor and Tenenbaum, 2007).

8.3.1 Generalized factors of sport-specific abilities

At least four generalized informative factors determine sport-specific abilities and require a correct and concise description in both group and individual models: body build, body composition, relevant physiological capabilities, and sport-specific motor abilities (Table 8.5).

Table 8.5
Modeling of sport-specific abilities: generalized factors and characteristics

Factors	Characteristics	Comments
Body build	Height, length of extremities, body breadths, body weight; somatotypical indicators	These estimates are necessary for modeling the "ideal athlete" in a given sport
Body composition	Fat component, lean body mass, muscle mass	These estimates are necessary for individual models to monitor a specific athlete
Physiological capabilities	Maximal oxygen consumption, anaerobic threshold, maximal blood lactate, maximal oxygen debt etc.	Both general (for certain sports) and individual model characteristics can be proposed
Sport-specific motor abilities	Maximal speed, power, strength, endurance, flexibility and agility in sport-specific motor tasks	Model characteristics can be proposed for selecting the most promising candidates and for individual training control

The impact of the factors mentioned above differs in various sports and their interrelationships are also sport-specific. For instance, it is generally accepted that a specific body build predisposes one to a given sport. Similarly, appropriate physiological preconditions help elicit more or less favorable training responses and progress in specific sports. Therefore, the generalized models of "ideal athletes" can help to better evaluate several candidates; the individual models, which are usually prepared for high-level athletes, can assist in monitoring the training and guiding the preparation.

In addition to the four factors mentioned above, psychological characteristics are definitely very important. The problem is that psychological traits of successful athletes vary over a wide range of manifestations. Nevertheless, several personality qualities can be sufficiently described and inserted into generalized models for certain sports (Van den Auweele et al., 2001). Likewise, psycho-sensory characteristics such as time, rhythm and force reproduction can be used for individual diagnostics and modeling.

8.3.2 Body build and body composition

The models of sport-specific body build have traditionally been developed on the basis of investigations of groups of highly successful elite athletes. Interest in this category of athletic prognostication remains consistently high: a number of scientific projects have been conducted in the framework of the Olympic Games, where elite athletes have been studied with respect to their sport-specific anthropometric status. These include the 1964 Tokyo Olympics (Hirata, Kaku, 1968), the 1972 Munich Olympics (DeGaray et al., 1974), the 1976 Montreal Olympics (Carter et al., 1982) and others. The modeling approach presupposes that average data of a sub-population of elite athletes can be used for compiling a generalized model of body build for the corresponding sports. One of the last anthropometric studies of Olympians was conducted during the 2000 Sydney Olympics with canoe/kayak paddlers and rowers (Ackland et al., 2001).

> **Study and example**. 296 rowers and 70 canoe/kayak flatwater paddlers representing 35 countries were examined using a battery of 35 anthropometric measures. The normative data obtained by the researchers characterizing body size, proportionality and composition can be employed to compile descriptive models of elite athletes in corresponding sports. Several selected estimates (Figure 8.4) display specificity for the sub-populations examined and make it possible to characterize salient anthropometric traits, which can be used for preliminary team selection and general orientation (Ackland et al., 2001)

Insert Figure 8.4 about here

Even a brief glance at the above data makes it possible to recognize somatotypical particularities of world-ranked rowers and canoe/kayak paddlers: tall robust persons with long extremities and low fat component. As was already stated (see 3.1) body characteristics such as body length are strongly dependent on heredity. It is known that body build can be changed slightly with athletic preparation (Wilmore & Costill, 1993). Therefore, appropriate body build models can be proposed for lower level and junior athletes. Based on such a model, tall teenagers with long arms and low fat component can easily be recognized as suitable candidates for prospective rowing and kayaking groups. Likewise, the appropriate body build models in various sports can help in the preliminary selection of gifted children and potentially successful team members.

Unlike body build, body composition can be substantially changed with training and appropriate diet. Generally speaking, two major elements determine body composition: the fat component, and lean body mass, that is body mass without fat (bones, muscles, internal organs, skin etc.). It has already been noted that training monitoring can be remarkably enhanced by controlling body mass and the fat component (Tables 6.8; 6.11; and 6.14). Both research findings and practical observation indicate that substantial alterations of body composition occur under various circumstances. These are the most typical cases:

- increase of fat component due to excessive dietary intake;
- increase of fat component when dietary intake is constant but energy expenditure is reduced (for instance, in taper);
- reduction of muscle mass (and lean body mass) due to catabolic action of stress hormones associated with emotional tension;
- reduction of muscle mass (and lean body mass) due to catabolic action of cortisol during altitude training (see 9.1.2);
- reduction of muscle mass when the residual training effect of the preceding hypertrophy program is attenuated.

It is obvious that variations of body composition are very specific in different sports. Marathon runners, soccer players and heavyweight wrestlers differ enormously in body mass, fat component, and they vary considerably during training. Therefore, sport-specific models for certain athletic sub-populations can serve the same purpose as body-build models. However, individual models of body composition can effectively contribute to training monitoring and assist in guiding preparation.

Case study. The follow-up program of world-class swimmers Alexander Popov and Michael Klim included systematic anthropometric monitoring using a specially constructed original index. Over a period of six years body mass (BM-kg) and sum of 6 skinfolds (SSk-mm) were measured at the initial and culmination phase of each training stage. Their ratio gave an indication of individual body composition status. When body mass was stable or slightly increased but fat component increased sufficiently, the ratio BM/SSk declined and this was typical for the beginning of a training stage. When muscle mass increased and fat component decreased, body mass remained stable, but skinfold sums decreased remarkably. Correspondingly, the BM/SSk ratio rose and this was typical of the culmination phase of the training stage just prior to the competition (Table 8.6). These individual variations were analyzed by the personal coach of both swimmers, Guennadi Touretski, who immediately corrected the program following marked deviations. Therefore, individuals using this index try to have their values correspond to these top-performance athletes (by courtesy of Guennadi Touretski, personal communication).

Table 8.6
Individual variations of Body Mass/Skinfold Sum ratio in world class swimmers

Athlete	Range of variations	Variations at the beginning of stage	Variations at the culmination of stage
Alexander Popov (RUS)	2.04 – 2.45	2.04 – 2.23	2.3 – 2.45
Michael Klim* (AUS)	1.6 – 2.57	1.6 – 2.1	2.2 – 2.57

- Michael Klim –two-time Olympic Champion, three-time Olympic silver medal winner, many time World Champion and medal winner in swimming

Summarizing the data, it can be stated that body build models have primary importance for orientation and for the preliminary selection of athletes for certain sports and disciplines, while the body composition model can optimize training monitoring and individual diagnostics of high-performance athletes.

8.3.3 Physiological capabilities

Both sub-population and individual models of physiological capabilities can contribute considerably to athletes' preparation. Certainly, the selection of physiological variables that should be included in the model depends first of all on specific demands of the sport. Such characteristics as maximal oxygen consumption and anaerobic threshold are relevant for many sports and definitely for ball games. Thus, the appropriate model characteristics of these indicators can be used for general evaluation of candidates for several teams (Figure 8.5).

Insert Figure 8.5 about here

Study and example. Four groups of qualified players (each one – 40 male athletes) from different ball games were examined with respect to various physiological functions. The highest values of maximal oxygen consumption and anaerobic threshold were found in soccer players; handball players had somewhat lower values but they were superior to basketball and volleyball players (Figure 8.5). The highest anaerobic alactic abilities were found in soccer and volleyball players while the highest anaerobic glycolitic power and capacity were obtained in basketball players. Thus, sport-specific physiological demands determine the general development of certain physiological abilities and this should be taken into consideration when compiling corresponding models of physiological capabilities (based on Jaruzhnyj, 1993).

Compilation of individual models of physiological capabilities seems very promising and useful for practical implementation although several methodological difficulties can are discernible. For example, such a model presupposes the prediction of individual upper limits of the function being evaluated and this requires a correct and scientifically proven procedure, which is still not in common use.

8.3.4 Sport-specific motor abilities

Examination of sport-specific motor abilities usually does not require expensive sophisticated equipment and can therefore be found in the domain of coaching routine. The usefulness of such models is apparent: a group model serves as the set of norms, which make it possible to objectively evaluate merits and demerits of each athlete in comparison with the desired level; the individual model makes it possible to monitor changes in sport-specific physical fitness induced by training. Group models can be easily be compiled for different athlete categories including elite and sub-elite.

Example. The Russian artistic gymnastics national team, one of the most successful in the world, actively utilized modeling approaches for both technical and physical preparation. Over a number of decades, sport-specific motor fitness has been evaluated by a test battery that contains a number of carefully selected exams. The model of sport-specific motor abilities proposed for the national team gives model characteristics, which serve as the norms for all team members and potential newcomers (Table 8.7). The importance of this model can not be underestimated. An additional benefit of this model is that each high-performance gymnast can independently estimate his/her own physical fitness against the national team level (Arkajev & Suchilin, 2004).

Table 8.7
Model of sport-specific motor abilities in high-level male gymnasts
(by Arkajev & Suchilin, 2004)

Motor abilities	Tests	Indicator	Model characteristics
Maximal speed	Running 20 m	Time, s	3.0 – 3.1
	Run to vault	Velocity in last 5m prior take-off, m/s	7.8 – 8.2
Explosive strength	Standing high jump with arm swing	Height, cm	60 - 65
Isometric strength	"Cross" on the rings	Sustaining time, s	5 – 6
	"Inverted cross" on the rings	Sustaining time, s	5 - 6
	Hanging scale on the rings	Sustaining time, s	5 - 6
	Support scale on the rings	Sustaining time, s	5 - 6
Dynamic strength	Climbing up a rope to 4 m height using arms only	Time, s	5 – 5.5

Individual fitness models can be developed with respect to specific demands on and particularities of an athlete. Based on a coach's estimation, one athlete may need to reinforce the strength component of his/her performance, while another one should improve his/her endurance. Correspondingly, the individual models of these two athletes emphasize respective demands and give them additional motivation to reduce the gap between the actual and desired levels of sport-specific fitness.

Both collective and individual models of sport-specific motor abilities serve to facilitate training by eliminating or at least reducing the gap between modeled and available level of athletic fitness. In other words, a reasonable and well balanced individual model can serve as an efficient instrument to motivate athletes to work conscientiously towards a specific goal. Usually such models are compiled for rather qualified athletes and they are particularly suited for helping ambitious young individuals to progress. We can see this approach in action through the example of a junior high-performance kayaker.

Example. A 17-year-old athlete with three years of experience in kayak training underwent a motor fitness battery that included six tests: pull ups, one-minute bench pull with a 40 kg barbell, one-minute bench press with a 50 kg barbell, sit ups during two minutes, 3 km run, and one arm kayak stroke simulation in sitting position on a pulley machine with a 40 kg weight, one minute for each arm separately. The initial findings revealed that the athlete had a relatively high level of running endurance, but insufficient strength endurance of arms and in particular abdominal muscles. As a result, his kayak-specific strength endurance in stroke simulation was far from the desired level. The individual motor fitness model was compiled with respect to the athlete's personal weaknesses (Figure 8.6). The athlete received special home tasks for individual morning workouts and additional motivation to focus on paddling resistance exercises. During the next six months the athlete substantially enhanced his fitness profile and approached the individual model. This gain resulted in impressive progress in the athlete's 500 and 1000 m kayak-single racing events.

Insert Figure 8.6 about here

It is logical that individual models for relatively young and developing athletes should be renewed each year following the general tendency of their progress while the models for aged athletes may reflect their stable state of sport-specific motor abilities.

8.4 Models of training programs

There are many ways to apply the modeling approach to planning and designing training programs. Nevertheless three basic categories of training models are widely used and can be recommended as practically oriented: structural models, models of training content and model characteristics of training workloads. Let us consider each of them separately.

8.4.1 Structural models

The structural models are intended to describe and analyze relations between several components and elements of training. There are two principal approaches to the structural modeling of training: the first one can be called the “scientific approach”, which has been used in a number of research projects; the second one serves mostly practical needs, and is intended to present the training system that can be understood more fully and used for serious planning.

The prospective scientific approach to training was proposed by Banister and colleagues (1991, 1999), who elaborated a mathematical model describing the interaction between fatigue and fitness and changes induced by daily training stimuli. The model postulates that performance level is determined by the difference between the negative function (fatigue) and the positive function (fitness). This model was used to quantify training workloads and predict performance progress. A similar approach was utilized in a study of taper in high-performance swimmers (Mujika et al., 1996). The researches quantified weekly training stimuli with respect to both the volume and intensity of exercises performed. The appropriate mathematic formulas allowed researchers to examine the interaction between the negative and positive impact of training (i.e., fatigue and fitness respectively); the modeled performances were calculated and were found to correspond highly with actual training outcomes. The fitness-fatigue theory was a major contributing element in the two-factor model proposed by Zatsiorsky (1995). Unlike the one-factor theory, which is based on supercompensation (see 1.3), the two-factor model explains the improvement in athletic preparedness as the result of continuous interaction between fatigue, caused by preceding workouts, and fitness, which is enhanced by training stimuli. The two-factor model can better explain how athletes improve their preparedness even in cases in which they do not attain full recovery.

The practical modeling approach comprises various structural schemes and descriptive models of training for the most part. A modeled presentation of training can be found in almost every textbook. The proposed descriptive model below is intended to display the hierarchy and main structural components of an annual training cycle according to the Block Periodization concept (Figure 8.7). The upper level displays competitions, which are categorized with regard to their importance. The second level presents training stages, each of which consists of three mesocycle-blocks which are placed on the third level. The fourth level presents several microcycles and the fifth, and lowest, level lists medical and other examinations, and training camps. This structural scheme does not add much knowledge to the Block Periodization concept but it can assist to better understand its essence. Besides providing concrete details and terms, this model can easily be transformed into a visual presentation of an annual training plan.

Insert Figure 8.7 about here

8.4.2 Models of training content

Usually models of training content present the principal and most essential characteristics of several training cycles. There are two popular approaches to training content modeling: using specialized computer programs that make it possible to compile the content of appropriate training cycles or units, and descriptive presentations of modeled training programs. The first approach has been utilized in several sports. One such example is presented below.

Study and example. A specialized modeling method was developed to determine velocity regimes for highly intensive swimming exercises. The model presupposes the classification of swimmers into 12 categories according to pre-determined individual records, a predisposition to short, medium or long distances, and the swimmers' capability level. A computer program calculates proper training regimes (content of exercises) adjusted specifically for Maximal Anaerobic Power, Anaerobic Capacity, and Aerobic Power. 22 highly qualified swimmers took part in verification of the model; the predicted and actual characteristics of modeled exercises were compared and a high correlation was found. The modeling program was successfully implemented in preparation of high-performance athletes in different countries (Issurin et al., 2001)

The second approach can be illustrated by the descriptive model of the final stage preparation of the very successful Russian male artistic gymnastics team.

During this period the athletes usually perform 17 workouts per week with one day off. The most important component of this preparation during this period is event simulation, i.e., the performance of competitive combinations on each apparatus such as the parallel bars, rings, pommel horse etc. The original model presupposes the performance of 10-40 competitive combinations on five apparatus per week and this load distribution follows the specific demands of pre-competitive preparation (Table 8.8).

Table 8.8
Model of the final stage preparation of the Russian male artistic gymnastics national team prior to the World Championship (by Arkajev & Suchilin, 2004)*

Type of microcycle	Number of combinations per day						Number of combinations per week
	MON	TUE	WED	THU	FRI	SAT	
Restoration	no	1×5	no	no	1×5	no	10
Adjustment	1×5*	no	1×5	no	1×5	1×5	20
Loading	1×5	1×5	1×5	no	1×5	1×5	25
Impact	2×5	no	2×5	no	2×5	2×5	40
Modeled competitive	1×5	1×5	1×5	1×5	1×5	1×5	30
Loading	1×5	1×5	1×5	1×5	1×5	1×5	25-30
Loading	1×5			1×5		1×5	25-30
Pre-competitive	1×5	no	1×5	no	1×5	1×5	20

*Note: 1×5 means that the athletes perform one competitive combination on five types of apparatus. The number of vaults usually varies between four and six.

As in the above example, many prominent coaches in various sports offer approved models of certain mesocycle, microcycle and key-workouts. The more or less standardized content of these training cycles allows them to compare modeled and available outcomes and evaluate the quality of training more objectively.

8.4.3 Model characteristics of training workloads

Model characteristics of training workloads contribute in terms of methodology, organization and motivation. They provide coaches and athletes with a general and quantitative orientation for training demands and the desired proportions between workloads performed at specific intensity levels. Now, with the growing popularity of cooperation between coaches from different countries, the basic parameters of training workloads are generally known and considered. As a result it is possible to present and compare the most comprehensive model characteristics of annual training workloads for highly qualified athletes from several types of endurance sports (Table 8.9).

Table 8.9
Tentative version of model characteristics of annual training workloads in highly qualified male athletes for several endurance sports (based on Giliazova et al., 1987; author's own modification)

Sports	Total volume, km	% ,*Intensity zones					Number of performances
		I	II	III	IV	V	
Running middle d.	4300	41	47	6	4	2	28-35
Running long d.	7000	30	58	7	4	1	16-20
Swimming 200-400 m	2300	25	46	20	7	2	60-80
Kayaking	5000	42	32	17	7	2	50-70
Rowing	6300	56	40	2.7	1	0.3	25-30
Road cycling	35000	10	70	18	2	0.2	70-100
Speed skating	8500	20	51	23	5	1	45-50
Skiing	9000	21	35	33	11		30-40

* - intensity zones are defined according to following values of BL accumulation (in mM): I- to 2.5; II – 2.5-4; III – 4-8; IV – more than 8; V – alactic bouts, BL is not relevant

It can be suggested that the total volume of sport-specific exercises is more or less equivalent, taking into account differences in velocity and in duration of competitive performance (e.g., two minutes for swimming 200 m vs. four hours of road cycling). However there are striking differences in the number of competitive performances in various sports, this despite the tendency to increase performance in competitions and reduce the training routine part.

A salient discrepancy can also be noted in the proportions of partial volumes of exercises performed at different intensity zones. For instance, several top-level rowers perform more than 50% of their exercises in the first intensity zone and some coaches suppose that this volume should approach 90%. From the viewpoint of cyclists and long distance runners, such excessive volume of low intensive work is a waste of time and they have arguments to support this position. Nor it is true that different coaches within the same sport are more in agreement. Thus, the question arises whether it is really worth establishing model characteristics if experts vary so much in their opinions. The answer is a definite yes. The following arguments support this statement:

1) Developing model characteristics of training workload stimulates a coach's creativity; this process demands retrospective analysis and an examination of reserves when planning and guiding preparation;
2) When model characteristics are proposed, both coach and athletes pay special attention to training regimes; training becomes more conscious and manageable;

3) Stage control and objective indicators take on greater importance; they make it possible to evaluate which part of the workloads was sufficient and which part was excessive.

Unfortunately not every mode of exercises can be expressed numerically in kilometers, tons or hours. Consequently, the possibility of compiling workload model characteristics in aesthetic and combat sports is less likely. Nevertheless, the modeling approach can also be implemented in non-measurable sports, although this demands additional efforts for characterizing workloads.

Summary

The modeling approach to planning and guiding athletes' preparation has become an efficacious tool for enhancing quality of training. The three-level model is proposed to characterize the entire preparation process. The upper level contains the top-performance model that relates to targeted result (in record sports), optimal performance, and proper tactics, technique and competitive behavior. The middle level embraces sport-specific abilities, which are necessary to obtain the planned (modeled) performance. This level relates to anthropometric status, motor and technical abilities, mental skills and effective knowledge. The bottom level presents the model of training programs, i.e., the most relevant characteristics of preparation such as total and partial training volumes, number of competitions, patterns of mesocycles-blocks etc. In actual practice the collective models for athletes' groups are more popular although each high-performance athlete can and should have an individual model.

A model of top-performance tends to assist athletes in realizing their athletic potential more completely. The general principle guiding this approach is that the top-performance model should be as deterministic as possible, i.e., each action and detail that is predictable or knowable in advance should be programmed for. This also applies to pre-event behavior including warm-up and mental tuning. It is important to remember that two relevant factors help determine the desired product: (a) – precision and completeness of the proposed performance model; (b) - precision and completeness of the competition analysis that reveals the extent of model realization.

The model of sport-specific abilities encompasses at least four generalized factors determining the athlete's potential: body build, body composition, relevant physiological capabilities, and sport-specific motor abilities, i.e., motor fitness. The results of the examination of elite athletes contribute to the development of a generalized model of body build for corresponding sports. Unlike body build, body composition can be substantially altered through training and appropriate diet. The proper control of body composition for high-performance athletes requires reasonable individual models of the fat component and lean body mass. Likewise, collective and individual models that include the most valid physiological capabilities and sport-specific motor abilities make it possible to monitor training properly and motivate athletes to show more initiative and be more conscious of their work.

Models of training programs are intended to help enhance the planning, design and guidance of training. They can be subdivided into three basic categories: structural models, models of training content and model characteristics of training workloads. Training structure modeling has been used in a number of research projects; for more practical needs, various descriptive structural models of training have been proposed. Similarly, training content models can be compiled using computer technologies and schematic descriptions of the most essential components and details. Integrative model characteristics of training workloads, which reflect the most important training requirements, can serve as the ultimate results of planning and make it possible to enhance the quality of preparation.

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Chapter 9. Altitude training

Altitude training has been a highly disputed branch of sport science; over the last three decades it has been a subject of intense interest to researchers and coaches. Generally speaking, the present situation is paradoxical. Publications written for coaches consider altitude training to be an efficacious and proven tool for enhancing high-performance preparation (Fuchs & Reiss, 1990; Dick, 1992; Suslov et al., 1999) while exercise physiology textbooks and professional reviews declare that altitude training provides no more benefits for sea level performances than proper conventional training (Jensen & Fisher,1979; McArdle et al., 1991; Wilmore &

Costill, 1993; Saltin, 1996, inter alia). From a practical viewpoint, the positive experience of prominent coaches, great athletes and several national teams offers strong arguments for employing altitude training. At present altitude training is incorporated as part of preparations for many successful national teams, particularly for endurance sports. Thus, this chapter is intended to summarize the current body of physiological and methodological data concerning altitude training with respect to designing the training programs. Therefore the scientific background presented here is restrictedly and curious readers are advised to refer to other sources (see reviews of Boning et al., 1997; Rusko et al., 2004; Wilber, 2004 and others).

9.1. Scientific background

As is well known, sport related scientific studies were initially stimulated by the organization of world-level competitions at altitude: the 1955 Pan-American Games held in Mexico City (elevation 2300m); the 1960 Winter Olympic Games in Squaw Valley (elevation 2000m); and in particular the 1968 Summer Olympic Games in Mexico City. At that time, earlier studies and pilot investigations concentrated on elaborate rational training programs at altitude in order to succeed in altitude performances. Later, when the basic knowledge had already been accumulated and various training facilities in altitude became available, systematic training at altitude to enhance sport performance at sea-level was introduced. Since then, the amount of scientific information on altitude training has increased constantly. Some of the relevant data are reviewed below.

9.1.1. General factors affecting altitude performance

Two general factors affect athletic performance at altitude: aerodynamics and physiology. As is well known, sea level air density diminishes with increased altitude. Thus, air density at 2300m (the altitude of Mexico City) is about 20% less than at sea level. Certainly, the reduction of air density and the corresponding decrease of aerodynamic resistance to locomotion allow higher velocities to be attained. The results of the Mexico City Olympics in sprint events corresponded to this theoretical position. Winning Olympic sprinters attained their personal best results in spite of the more difficult physiological conditions of performance. Moreover, Bob Beamon's new Olympic and world record for long jump bettered the previous one by 55cm (!) – an unheard of accomplishment.

Unlike the aerodynamic factor, the impact of altitude on physiology is strongly negative, first of all because of the decreased partial pressure of oxygen in ambient air. This lower oxygen content immediately reduces athletes' aerobic abilities during the initial period of altitude acclimatization. The general explanation of this fact is that decreased oxygen content in the atmosphere reduces oxygen blood saturation and delivery to the muscle cells. Hence, in the long distance events, where oxygen supply is of high importance, athletic performances tend to decrease and this tendency is clearly demonstrated by the results in the Mexico City Olympics (Figure 9.1).

Insert Figure 9.1 about here

The above graph clearly shows the advantageous zone – sprints including the long and triple jumps; and the disadvantageous zone – endurance events, where performance decreased as distance lengthened. Of course, a factor such as adaptation to altitude conditions was extremely important in medium- and long-duration events. Residents and especially natives of altitude places enjoy big benefits in terms of oxygen delivery and utilization. It is noteworthy that in the Mexico City Olympics, the gold and silver medals in the running 5000m, 10000m, marathon and 3000m steeplechase events were won by natives of altitude-based countries: Ethiopia, Kenya, and Tunisia. It was obvious even before the Mexico City Olympics that altitude performances aside from short-duration events require preliminary altitude training. However, after these Olympics both scientists and coaches focused their attention on another problem: How better to employ altitude training in preparing athletes for sea level performances.

9.1.2. Basics of altitude adaptation

Besides reduced air density and decreased oxygen content in ambient air, a number of environmental factors affect athletes' responses at altitude, namely: increased sun and ultra-violet radiation, reduced temperature and humidity, delightful landscapes and mountainous beauty. Traditionally, consideration of altitude exposure and training is focused on the hypoxia factor; but in fact, many environmental factors operate collectively and this determines the athletes' response. As it is known, the considerable effects of altitude exposure start from an elevation of 1600m; altitudes higher than 2600m are usually not utilized for training camps.

Let us consider the responses that occur during initial exposure: acute responses lasting from a few hours to a few days; and longer-term responses lasting two-five weeks or even more (Table 9.1).

Table 9.1
Acute and longer-term responses of athletes to altitude exposure and training (based on McArdle et al., 1991; Brooks et al., 1996; Wilber, 2004)

Physiological functions	Acute responses	Longer-term responses
Pulmonary ventilation	Increased pulmonary ventilation due to reduced oxygen content	Pulmonary ventilation remains increased
Heart rate	Increased heart rate at rest and during exercises; decreased maximal heart rate values	Return of exercise and rest heart rates to pre-altitude level; maximal heart rate remains decreased
Stroke volume	Reduced stroke volume at rest and during any intensive exercise	Return of exercise and rest stroke volume to pre-altitude levels
Cardiac output	Reduced cardiac output at rest and during any intensive	Return of exercise and rest cardiac output to pre-altitude

	exercise	levels
Blood lactate	Increased lactate accumulation after intensive and maximal exercise	Decreased lactate values after intensive and maximal exercise as compared with pre-altitude levels
Aerobic energy supply	Reduction of maximal oxygen uptake by 1% for each 100m of altitude elevation	Increase of aerobic enzymes; return of maximal oxygen uptake to near pre-altitude levels
Anaerobic capacity	Hypoxia accelerates glycolitic reactions and glycogenolysis	Increased muscle buffering enlarges anaerobic capacity
Hormones regulation	Increased catecholamine level; release of erythropoietin that stimulates production of erythrocytes and hemoglobin	Increased cortisol that indicates stress reaction and affects muscle catabolism
Hematological responses	Plasma volume and total blood volume decrease immediately after arrival	Increased total blood volume, number of erythrocytes and mass of hemoglobin
Skeletal muscles		Increased capillary density; possible muscle mass decrease due to cortisol catabolic action
Fluid balance	Tendency to dehydration due to increased respiratory and urinary water loss	Increased fluid intake can be as much as four-five liters per day
Immune system	Increased risk of upper respiratory infections	Increased level of stress hormones (catecholamines, cortisol) suppress immune function

Let us consider the scenario of physiological changes induced by exposure to and training at medium level altitude. Arrival at altitude and breathing air with lower oxygen content causes an excitation of chemoreceptors and a reflexive increase in pulmonary ventilation. This increase is a compensatory mechanism to bring the same amount of oxygen into the lung as at sea level. Such hyperventilation occurs both at rest and during exercise. The blood plasma volume declines immediately after arrival at altitude; after a week or more it returns to pre-altitude levels and even increases above sea-level values (Saltin, 1996). Heart rate at rest and during moderate workloads elevates proportionally to the decrease of partial pressure of oxygen. An additional reason for the heart rate increase could be also catecholamine excretion (mostly adrenalin) that occurs in particular at initial exposure. Stroke volume at rest and during moderately and highly intensive workloads decreases substantially within the initial two days. After a number of days stroke volume returns to pre-attitude levels. Nevertheless, heart rate increases markedly, and cardiac output remains decreased at rest and during various workloads for several days (Wilber, 2004). One of the important outcomes of hypoxia is reduction of kidney oxygenation that stimulates synthesis of erythropoietin (EPO), a hormone that regulates production of erythrocytes and hemoglobin. The increased concentration of EPO elicits synthesis of additional erythrocytes and hemoglobin, a process that takes approximately five-seven days. After that, oxygen carrying capacity of the blood increases markedly as does athletes' aerobic ability. These perturbations explain the dramatic reduction of maximal oxygen uptake during acute exposure and its gradual increase during acclimatization. In the initial days, the hypoxic environment accelerates glycolitic reactions and glycogen breakdown. At this time anaerobic threshold dramatically decreases and the corresponding velocity regimes decrease as well. Correspondingly, the metabolic response to habitual exercise changes as well; as athletes approach their previously comfortable velocity regime there is a sharp increase in blood lactate. Further acclimatization follows to increase muscle buffering capacity that prevents excessive acidosis (pH reduction) during severe workloads.

Serious altitude training over a week or a little more leads to increased secretion of cortisol that stimulates catabolic reactions and possible reduction of muscle mass. Indeed, remarkable decreases of muscle mass and body weight have been noted among top-level athletes (Issurin, Kaverin, 1990). One more consequence of increased cortisol is suppression of the immune function with increased risk of upper respiratory infections a concern of sport physicians. Immediately after arrival at altitude increased respiratory and urinary loss of water may cause dehydration. Therefore, during the entire altitude exposure, fluid intake should be increased by four-five liters per day.

For a long time the potential benefits of the altitude training were associated with hematological changes, i.e., increased oxygen delivery to muscles. In fact these changes are transient and very soon after returning at sea level (a few days to one week) erythrocytes and hemoglobin return to pre-altitude levels. Another potential contributor to the post-altitude ergogenic effect is enhancement of anaerobic abilities due to increased buffering capacity of muscles and blood. An additional potential contributor may be enhanced cellular adaptation of muscles. This factor has been studied less and is rarely considered. Nevertheless, it is known that training at altitude (or altitude-simulated conditions) leads to increased muscle capillarity, which facilitates oxygen extraction from the blood (Mizuno et al., 1990). Other favorable changes can also occur in the muscular microstructure (Terrados et al., 1990).

Study and example. Ten male subjects trained for four weeks on a cycle-ergometer with one leg. The training protocol consisted of exercising one leg under normobaric (sea-level) conditions, and another leg under hypoxic conditions corresponded to an altitude of 2300 m. Tests battery included endurance trials and needle biopsy with subsequent evaluation of muscle enzymes and myoglobin in the extracted sample. Comparison of altitude-trained leg with the other one allowed researchers to assess the effect of altitude-simulated training. It resulted in significantly superior endurance, markedly increased activity of oxidative enzymes and a higher concentration of myoglobin (Terrados et al., 1990).

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In summary, even a simplified consideration of acute and longer-term responses to altitude exposure indicates many difficulties related to athletes' preparation planning while the potential benefits still look complicated and dubious.

9.1.3. Does altitude training provide benefits?

Although this question is not relevant for many coaches, it remains very tangible for many physiologists. Generally speaking the existing situation is paradoxical: exercise physiology textbooks declare that altitude training provides no benefits for sea level performances compared to appropriate training at sea level (Jensen & Fisher,1979: McArdle et al., 1991; Wilmore & Costill, 1993; Brooks et al., 1996). Nevertheless, the number of athletes practicing at altitude camps as well as the number of altitude training centers is constantly increasing. Many great athletes from different sports like Alexander Popov (swimming) or Lance Armstrong (cycling) systematically used altitude camps. For instance, Frederick (1974) showed that all gold medals in running events from 1500m through the marathon at the 1972 Munich Olympics were won by athletes who used altitude training. Despite the scientific contradictions and areas of theoretical dispute, altitude training has become a component of the preparation regime among many successful national teams.

Case study. During the 1999 European swimming championship, the head coaches of leading national teams (Germany, Great Britain, France, Italy, Russia, Spain and Sweden) were questioned by this author on the use of altitude training. All respondents reported that their teams practiced in altitude training camps as part of their annual preparation. However, each of them noted that several athletes, usually the older and more experienced members of the team, did not take part in altitude camps. The reasons offered by the different coaches were very similar – unfavorable response by athletes to altitude training

The above example demonstrates that prominent coaches, supported by qualified sport experts and physicians, make a conscious choice to incorporate altitude training in their preparation regimes. It is hard to imagine that they didn't find sufficient arguments for incorporating altitude programs over the decades. At the same time, however, the same example indicates that not all members of a national team participated in the altitude program; exceptions were noted in each team. The coaches solved the problem by dividing athletes into "responders" and "non-responders" and then releasing the latter from altitude programs. This practical approach is completely consistent with scientific data showing that "responders" and "non-responders" are recognizable on the basis of hematological responses and rate of performance gain (Chapman et al., 1998). Additional support of this concept can be found in human genetics studies.

Genetic evidence. Scientists have long investigated common genetic markers to determine whether there are differences in genotype frequencies between top-level athletes and control populations (de Garay et al., 1974). The 14^{th} human chromosome was found to contain the so-called Hypoxia-Inducible Factor 1α that serves as a genetic regulator of EPO synthesis and release during altitude exposure and training (Vogt et al., 2001; Wilber, 2004). Athletes with a genetic predisposition to a favorable response to hypoxia release much higher concentrations of EPO at altitudes (Witkovski et al., 2002). Apparently these athletes manifest beneficial hematological changes induced by altitude training.

It should be noticed that investigation of altitude training effects have resulted in very different outcomes. Several research groups find no post-altitude improvement in physiological variables (hematological changes, maximal oxygen consumption) or in athletic performance (Hahn et al., 1992; Telford et al., 1996; Balley et al., 1998). The other studies reported significant gains both in maximal oxygen consumption and athletic performance (Chung et al., 1995; Levine & Stray-Gundersen, 1997). These contradictions can be partly explained by "responders vs. non-responders" concept. From this viewpoint it is interesting to consider the findings, which were obtained in a group consisting of "responders" only.

Study and example. Seven highly qualified middle- and long-distance runners underwent a three week training camp at altitude (1850 m). Each of them systematically used altitude training over a number of years and their positive responses were confirmed by distinct performance gains. Maximal oxygen consumption was determined prior to altitude camp and on the third week of sea level re-acclimatization (Figure 9.2). All runners improved their pre-altitude aerobic ability and the average gain for the entire group was significant ($P<0.05$): 7.4% (Suslov et al., 1999).

Insert Figure 9.2 about here

Summarizing the preceding section, it can be proposed that athletes belonging to the "responders" category can benefit from rationally designed altitude training. Which physiological factors contribute what would be called the post-altitude ergogenic effect? A review of current world literature allows us to list three potential benefits of altitude training (Table 9.2).

Table 9.2.
Potential benefits of altitude training affecting performance enhancement at sea level

Potential benefits	Comments	Sources
Improved oxygen delivery to muscles	Lower oxygen in ambient air elicits a synthesis of the hormone erythropoietin (EPO) that stimulates production of additional red blood cells and hemoglobin, which provide beneficial delivery of oxygen to muscles; total blood volume increases as well	Saltin.,1996; Ekblom & Berglund, 1991
Enhanced oxygen utilization within the muscle cells	Altitude training increases concentration of myoglobin, activity of aerobic enzymes and number of mitochondria; muscles capillarity increases as well	Terrados et al.,1988,1990 ; Mizuno et al., 1990
Increased anaerobic capacity via improved buffering in muscles and blood	Altitude training increases ability of blood and muscles to buffer the concentration of hydrogen ions and prevent excessive acidosis; as a result athletes' anaerobic capacity increases	Mizuno et al., 1990 ; Gore et al., 2001

Further consideration of the benefits listed requires a number of critical remarks. Unfortunately, increased erythrocyte numbers and hemoglobin mass fall quickly after returning to sea-level (Wilmore & Costill, 1993), although larger blood volume takes 2-4 weeks before it gradually normalizes (Saltin, 1996). It could be suggested that the blood of some athletes retains increased oxygen carrying capacity for longer periods while in others this benefit is lost faster. The improved cellular adaptation of muscles caused by altitude training seems a likely candidate for potential benefits, but at present there is little to support this hypothesis. Increased anaerobic capacity looks like a real candidate for benefiting sea level performance; it helps explain why many top-level sprinters (400 m runners, 100 m swimmers, etc.) have continued to use altitude training camps over the last three decades.

9.2. Training fundamentals

Apparently, the physiological responses to altitude training are very different from training at sea level. Consequently, training programs at altitude should reflect these differences. They must correspond to physiological demands and don't exceed the limits of biological adaptation; on the other hand they should provide the planned cumulative training effect. Therefore, appropriate general principles, basic methodology and practical guidelines are required. They will be presented below.

9.2.1. General principles and basic positions of altitude training

The following four general principles are of primary importance for training and coaching.

First – The general goal principle. One of three options should be selected:

- Is altitude training intended to prepare athletes for altitude performance?
- Is altitude training supposed to exploit post-altitude effects in sea level competitions?
- Is altitude training intended to diversify and activate annual preparation?

Second – Selecting the athletes who positively respond to altitude training. The decision to include each individual athlete in the altitude program should be made with respect to his/her individual responses, previous altitude experience and data of relevant medical examinations.

Third – Compiling the training program according to phases of altitude acclimatization. Pre-altitude training, altitude conditions (elevation, climate, weather etc.) and individual particularities of the athletes (previous experience at altitude, age, body weight and muscle mass, aerobic capacity etc.) affect the duration of each phase.

Fourth – Compiling the post-altitude training program with respect to phases of sea level re-acclimatization. This principle also involves participation in competition and utilization of the post-altitude ergogenic effect.

Let us comment on the above principles and consider the basic elements of planning altitude training. The first principle relates to preparation strategy, when coaches and sport administrators decide to develop their training concept including altitude training. There are at least three general purposes of altitude training and each of them determines the proper characteristics of annual preparation (Table 9.3).

Table 9.3

Purposes and general characteristics of altitude training in the framework of athletes' annual preparation cycle

Purpose of altitude training	Types of mesocycles employed	Number of altitude camps	Total altitude exposure
Athletes' preparation for sea level performance	Accumulation Transmutation	Two-three	35-60 days
Athletes' preparation for altitude performance	Accumulation Transmutation Realization	Three-four	50-100 days
Diversification and improvement of annual preparation	Accumulation	One-two	15-25 days

The use of altitude training for sea level performance presupposes the utilization of several potential physiological benefits considered previously (Table 9.2). From both the physiological and methodological points of view it is important to individually check athlete's responses and adapt him/her in advance for unusual workloads and reactions. It can also be hypothesized that utilizing physiological benefits provides more deterministic and predictable training responses in repeated altitude camps. In any case, the training systems exploiting the post-altitude effect, which were developed in the USSR (Suslov, 1983) and the GDR (Reiss, 1988), proposed strict adherence to two or three repeated altitude camps.

The second principle refers to the concept of "responders" and "non-responders" (Chapman et al., 1998). This differentiation can be made using objective scientific methods or with the help of practical sport-specific indicators. In any case this estimation demands one-two altitude camps where individual training responses can be checked. Practical experience shows that the majority of high-level athletes, particularly in endurance sports, respond positively to altitude training. Nevertheless even among "responders" the variability of individual reactions is very high. The most influential factor in adaptation is the accumulated experience from previous camps. It has been noted that athletes with more experience at altitude overcome initial acclimatization problems better and faster. This accelerated adaptation is achieved because of both physiological factors (more favorable hormonal reaction, better hematological response etc.) and more rational behavior during training and restoration. During the first camp young athletes (18-21 yr) usually respond more beneficially, relatively speaking. Additional advantages in initial adaptation give smaller muscle mass and higher aerobic capacity, which usually cause more economical and favorable responses.

The third and forth principles require special consideration that will presented in sections 9.2.2 and 9.2.3. Additional general remarks are required with regard to the usefulness of altitude training in different sports and the employment of altitude training as part of Block Periodization.

Traditionally, altitude training has been considered especially suitable to endurance sports (Saltin, 1996; Reiss, 1998; Rusko, 2004). In fact the spectrum of sports for which altitude training has been utilized is much wider. Objectives such as active recovery and general conditioning make reasonable use of altitude training in any sport. For instance, Soviet astronauts systematically practiced at training camps in the altitude athletic center in Armenia. Athletes from combat sports and ball games use altitude training to improve general and sport-specific endurance. In addition, potential benefits like enhanced anaerobic capacity (Table 9.2) can provide better speed endurance and this expands the range of athletic events for which altitude training is applicable. The power sports are also considered as activities that can benefit from altitude training (Suslov et al., 1999); the potential advantages that contribute to the positive effects relate mostly to general environmental factors and breaking the routine of habitual exercises. Nevertheless, the group with the largest number of altitude training proponents is formed by representatives of the endurance sports where the amount of scientific and empirical findings is really huge.

It should be emphasized that many years before the first publications about Block Periodization appeared, the idea of highly concentrated workloads directed at developing a minimal number of motor abilities was proposed with regard to altitude training. These altitude mesocycles were termed "blocks of aerobic workloads at altitude"; advanced coaches creatively combined these blocks with subsequent mesocycles of highly intensive workloads in a manner very similar to contemporary use of Block Periodization. Actually, the most widely used mesocycle at altitude is accumulation; more prolonged exposure at altitude makes it possible to conduct some part or even an entire transmutation mesocycle; in very special cases preparation for an altitude performance realization mesocycle precedes a competition (Table 9.4).

Table 9.4.
Proposed workloads and types of mesocycles used at altitude training

Proposed workloads	Type	Comments
General conditioning, low and moderate intensity aerobic workloads, use of semi-specific training means	Accumulation	Intended mostly for early season
Anaerobic threshold exercises, maximal strength or aerobic strength endurance workloads, use of alactic bouts	Accumulation	Intended mainly for mid season
Aerobic-anaerobic endurance and anaerobic glycolitic sport-specific exercises, anaerobic strength endurance workloads	Transmutation	Can be used only after sufficient acclimatization
General conditioning and sport-specific aerobic program intended to activate preparation to target-competition	Accumulation	Planned as initial part of Final Stage Preparation
Pre-competitive taper: event-specific simulation and maximal speed exercises combined with full recovery	Realization	Can be used prior to competition at altitude

9.2.2. Phases of altitude acclimatization and training program design

Altitude acclimatization is a highly complex process that is affected by environmental, physiological, training methodology and individual factors. Despite the complexity of this process and variety of individual responses three separate phases of acclimatization can be pinpointed (Table 9.5).

Table 9.5.
Phases of altitude acclimatization and their general characteristics
(Issurin & Vrijens, 1995)

Phases	Athletes' responses	Duration

Acute	Increased heart rate at rest and during exercise Substantially reduced velocity of anaerobic threshold Increased lactate accumulation during exercise with moderate intensity Increased pulmonary ventilation	3-7 days
Transition	Normalized reaction to exercise with low and moderate intensity Increased heart rate and lactate accumulation in intensive exercise Slightly reduced velocity of anaerobic threshold Increased pulmonary ventilation	3-5 days
Stabilization	Normalized reaction to exercise with low, moderate and high intensity Normalized lactate accumulation in intensive exercise Velocity of anaerobic threshold approaches to pre-altitude level Increased erythrocytes and hemoglobin mass	Rest exposure

The acute phase of acclimatization is the most restricted in terms of training capacity. For inexperienced athletes in particular, this period can elicit inadequate behavior reactions when excited athletes make excessive efforts and provoke exaggerated responses. These disorders can be associated with increased catecholamine secretion and reduced self-control. Duration of this phase strongly depends on the individual peculiarities of each athlete; usually it is shorter for athletes who have experienced a number of altitude camps.

The transition phase is characterized by more favorable but unstable and less predictable responses. In this phase the athlete can feel excessive fatigue after a relatively small load and movement technique may become less controlled. The duration of this phase also varies according to the individual; thus the total period during which athletes must train at reduced workloads varies from 6-12 days. Particular precautions are necessary about using highly intensive glycolitic exercises; employing them prematurely may adversely affect athletes' adaptation. Afterwards, when the stabilization phase is established, athletes are able to perform training programs with large workloads almost without limitations (Table 9.6).

Table 9.6
General approach to compiling a training program according to phases of altitude acclimatization (Issurin & Vrijens, 1995)

Characteristics of training	Acute phase	Transition phase	Stabilization phase
Type of microcycle	Adjustment	Loading	Loading and/or impact
Duration of microcycle	3-7 days	3-5 days	5-7 days
Number of microcycles	One	One	One - three
Total volume of exercise	Normal or 10-20% less	Normal or 5-10% less	Normal
Volume of exercise with higher intensity	40-60% less	15-30% less	Normal
Coordinative complexity	Lower	Slightly lower	Normal

As is shown in Table 9.6 the initial microcycle program strongly differs from the pre-altitude standard. Attempts to start an altitude program with the usual training regimes used at sea level have been made in various sports; the usual result was an inability to sustain the training program in the next microcycle. Moreover, as a rule such athletes also did not succeed in the re-acclimatization period and did not improve their sea level performances. Thus, the initial microcycle performed with a slightly reduced total volume of exercise, should exploit more economical workloads of reduced intensity and lower coordinative complexity.

During the transition phase total volume of exercise achieves its normal level but exercise intensity remains still lower. The stabilization phase allows and even requires the use of large workloads, which ultimately determine the cumulative and residual effects of the altitude program. This high workload level is sustained almost until the end of altitude camp. Nevertheless, during the last one-two days workload levels should be reduced in order to facilitate initial re-acclimatization at sea level.

The last aspect of this consideration concerns the duration of the altitude training camp. The general approach to determining the required duration of altitude exposure is presented in Figure 9.3.

Insert Figure 9.3 about here

If the entire preparation is intended to ensure success in altitude competition, the effect of altitude camp will be strictly determined by the gain of preparedness obtained in the stabilization phase. Consequently, it is reasonable to prolong work in this phase up to three or even four weeks. In this case the total duration of altitude camp can be one month or even more. If the program is intended to prepare athletes for sea level competition, its purpose is to attain a sufficient level of physiological adaptation and the camp duration can vary from 20-25 days, which corresponds to recommendations given by several training experts (Suslov, 1983; Fuchs & Reiss, 1990).

In conclusion two typical kinds of mistakes may be noted:

- Ignoring altitude specificity (or not giving it sufficient attention) when designing the training program and,
- Forgoing strenuous workloads when athletes are already adapted to altitude conditions.

9.2.3. Post-altitude re-acclimatization and athletic performance

The athletes' state during the period of re-acclimatization (i.e., training capacity and sport-specific performance) varies widely and is determined by at least three factors:

- phases of fitness deviations and physiological changes during this period;
- deviations of workloads during post-altitude training;
- individual particularities of athletes.

Periodical deviations of maximal performance and physiological state during post-altitude re-acclimatization were found and analyzed (Table 9.7).

Table 9.7.

Periodical deviations of athletes' state and maximal performance during post-altitude re-acclimatization

Period	Changes of athletes' state and maximal athletic performance	Sources
1st - 2nd days	Favorable state; it is possible to compete and attain good achievements*	Fuchs & Reiss, 1990
3rd-7th days	Reduced training capacity; low probability of attaining top performance	Schramme, 1970; Pohlitz, 1986
3rd -10th days	Depressive phase; participation in competition is not recommended	Fuchs & Reiss, 1990
14th-18th days	Continual increase of training capacity, attainment of top performance	Reiss et al., 1969; Suslov & Farfel, 1972
12th-28th days	Improvement of general and sport-specific reactions, successful athletic performance	Fuchs & Reiss, 1990; Suslov et al., 1999
37th-46th days	Delayed wave of improved athletes' state; high probability of successful performance	Suslov et al., 1999

From the data presented in Table 9.7, three positive phases of post-altitude re-acclimatization can be identified: the first two days after returning to sea level, the period between the 12th and 28th days, and a more delayed interval between the 37th and 46th days following altitude camp. The occurrence of the first and second positive phases is supported by many practical observations and is consistent with the findings of several well controlled studies (Figure 9.4).

Insert Figure 9.4 about here

The graph (Figure 9.4.) summarizes findings recorded after altitude training camps lasting 12-28 days at elevations of 1640-2500m. It shows that positive gains were obtained mostly during the initial two days and 16-20 days after returning to sea level; the majority of impaired performances were recorded between the 5th and 10th days of re-acclimatization. In general, the data reviewed from numerous studies support the existence of two positive phases in the post-altitude period. Concerning the third delayed phase, its occurrence deserves special comments. There are very few well documented studies in which athletes' states and performance were monitored for long periods after altitude training. One such project was carried out during the preparations of the USSR national swimming team.

Case study. Post-altitude performance trend was studied during preparation of the USSR national swimming team. The annual plan contained three altitude training camps lasting 20-22 days. During re-acclimatization after the last altitude camp the swimmers took part in a series of competitions within a 52 day period. The athletes competed in different events but their results were normalized with regard to season best performance and expressed in percentages (Figure 9.5). The best performances were obtained between the 42nd and 47th days and this period was considered as favorable and recommended for participation part in target-competition (Vaitsekhovsky & Suslov; cited in Suslov et al., 1999).

Insert Figure 9.5 about here

In view of above findings the post-altitude ergogenic effect can last much longer than previously expected (Figure 9.5). There is no evidence that hematological, enzymatic and cellular changes induced by altitude training can be maintained for such long periods. However, post-altitude benefits could have contributed to attainment of superior training effects, which led to the delayed best performances indicated above. It should be also noted that these impressive performance gains were obtained after the series but not from a single training camp. It can be suggested that they are the result of training responses produced by a series of altitude camps. Moreover, we can assume that swimmers with unfavorable responses to altitude training were identified in earlier stages of preparation and did not take part in the final altitude camp. This means that the observed delayed ergogenic effect was achieved by a sub-group of "responders", which could have been a valuable contributor to the progress attained.

High-performance sport offers many examples of successful preparation exploiting the post-altitude ergogenic effect. Most prominently, endurance athletes of the former GDR attained many outstanding results at the 1988 Seoul Olympic Games using properly timed altitude camps (Table 9.8).

Table 9.8.
Timing of altitude training camps of GDR national teams prior the 1988 Seoul Olympic Games (based on Fuchs & Reiss, 1990)

Sport	Altitude camp duration	Location and elevation	Time to 1st competition day	Time to last competition day
Swimming	23 days	Toluka, 2700	20	27
Rowing	23 days*	Kaprun, Silvretta; 1800m	17	23
Road cycling	18 days	Mexico; 2200m	41	45
Running: middle and long distances	28-33 days	Mexico; 2200m	22	30

* the rowing team had a preliminary 6 days of training in a hypoxic chamber before the altitude camp

In conclusion it can be said that during the last three decades many athletes and several teams from around the world have exploited the post-altitude ergogenic effect and have succeeded at sea-level competitions. Presumably, all of them belong to category of "responders" while their coaches belong to the category of "proponents of altitude training". Success in sea-level performance after altitude training programs can be attributed to three generalized factors:

- selection of athletes who respond positively to altitude training;

- utilization of positive phases of re-acclimatization in planning sea-level performances; and
- designing and creatively implementing a rational training program taking into account the positive and negative phases of re-acclimatization and the individual particularities of each athlete

9.2.4. Training stage containing the altitude camp

There are three different approaches to the of design of the training stage with altitude camp when preparation directed towards sea-level performance (Figure 9.6).

Insert Figure 9.6 about here

Let us consider the above diagram with respect to the particularities of each of the approaches.

Variant A - Altitude camp for general conditioning, diversification and active recovery: at this case the training stage can be started with altitude camp containing non-specific and semi-specific exercises for aerobic and general strength abilities; continuation at sea level is devoted to developing these abilities using sport-specific training means. The next transmutation mesocycle can exploit the positive phase of post-altitude re-acclimatization; the next realization mesocycle attends to the training stage.

Variant B - Altitude camp for sea-level performance in the second positive phase of re-acclimatization: the training stage is started with a pre-altitude training block lasting one-two weeks; it continues with an altitude camp consisting of "soft aerobic work" (acute and transition phases) and "hard work" (stabilization phase). The post-altitude program continues sport-specific preparation with transmutation mesocycle, pre-competitive taper and competition.

Variant C - Altitude camp for sea-level performance in third delayed positive phase (36-46 days after altitude camp): in this case post-altitude preparation is different. The athletes undergo post-altitude re-acclimatization and take part in competition immediately after the depressive phase (11^{th}-14^{th} days after returning at sea-level) or even a bit earlier. Afterwards the shortened accumulation and transmutation mesocycles precede the realization mesocycle of optimal duration prior to the target-competition.

Interestingly, variant B is the most widely used and discussed in the literature (Reiss & Zansler, 1987; Fuchs & Reiss, 1990), while variant C is less known and less popular. Let us now consider the separate components of variants B and C, namely: pre-altitude and post-altitude preparation.

Pre-altitude preparation is intended to facilitate athletes' adaptation to expected hypoxic conditions and planned aerobic workloads**.** For this purpose two basic approaches have been practiced: pedagogical and physiological.

The pedagogical approach presupposes administration of a sea-level block of aerobic workloads (one-three microcycles), with the program focused on extensive exercises performed at aerobic and anaerobic threshold levels combined with general conditioning exercises. Immediately before the altitude camp (two-three days) the workload level has to be reduced in order to facilitate acute acclimatization during the initial days of altitude camp. This approach is supported by publications of several experts in athletic training (Pfeifer, 1987; Reiss & Zansler, 1987).

The physiological approach employs special techniques to create hypoxic conditions during performance of the exercise program at sea-level. This hypoxic training is intended to attain pre-acclimatization before arrival at altitude. Widely used techniques for such training are hypoxic chambers (Wilber, 2004) or special masks for inhaling hypoxic air (Bulgakova et al., 1999). Pre-acclimatization training usually takes one-two weeks and can be completed immediately prior to or a few days before departure (Fuchs & Reiss, 1990). The number of workouts varies from three-six per week with workout duration of 30-90 min. Similarly, various other training regimes have been used although the most widely accepted seems to be continuous and intermittent exercises of moderate intensity.

> **Example**. Heinz Bubke, 50 km walking champion of the 1988 Seoul Olympics, practiced at three altitude training camps lasting three-four weeks at elevations of 2400m (Addis Abeba), 2700m (Toluka) and 2000m (Belmeken); the last one finished 19 days prior to Olympic performance. Pre-altitude training in a hypoxic chamber lasted one-two weeks prior to each altitude camp (source - Fuchs & Reiss, 1990).

Post-altitude preparation is based on previously considered phases of sea level re-acclimatization and changes in the athletes' state followed altitude training camp (Figure 9.7).

Insert Figure 9.7 about here

The first positive phase lasting two-three days has been exploited in athletic performances (sometimes successfully) but still remains problematic in terms of training design. Despite increased work capability, this phase includes profound physiological perturbations caused by drastic changes in environmental conditions. Many experts in athletic training suggest that this phase should be spent on moderate workloads focused on special conditioning, "soft" predominantly aerobic exercises and technical drills.

> **Example**. World-renowned swimming authority Gennady Touretski, who coached a number of world and Olympic winners including the legendary Alexander Popov, notes that the first two days after returning to sea level can be used for competitive performances, which can be rather successful. However, these high efforts usually aggravate the athletes' state in the subsequent period of re-acclimatization. He is convinced that this favorable state for athletes should be used to facilitate acute sea-level re-acclimatization; maximal competitive efforts are not recommended at this phase.

The general approach to training in negative post-altitude phases presupposes the use of exercise at aerobic and anaerobic threshold levels with a gradual increase in aerobic-anaerobic workloads. It is important during this period both to prevent excessive lactate accumulation and to involve sport-specific tasks with increased velocity regimens. A compromise between these contradictory demands can be attained with the help of interval series. Alactic bouts at submaximal power can be performed with a focus on "quality" but not on movement frequency. Athletes usually do not feel significant obstacles in techno-tactical drills; particular attention can be given to accentuated force application in continuous exercises with moderate intensity. After cessation of the negative phase work becomes more economical with medium and moderate intensity (lower heart rate and lactate accumulation); athletes reach enhanced specific feelings and better movement control. Highly intensive sport-specific exercises can be used without particular limitation. As was already stated, successful athletic performance can be planned for the period between the 14th and 28th days.

There are very few data on athletes' state after the second positive post-altitude phase. If the post-altitude training program is focused on a target-competition between days 36-46, the preceding period is devoted to pre-competitive preparation. Consequently, athletes' state during this period is determined mostly by current workloads, training residuals of previous work and, to a lesser extent, by delayed consequences of altitude adaptation. It can be suggested that the benefits of cellular adaptation, such as increased aerobic enzymes, myoglobin, and muscle capillarity, can be maintained for a relatively long period. There is evidence that additional training in hypoxic chambers is a successful approach during this period (Fuchs & Reiss, 1990). Such altitude-simulated workloads could prolong the previously obtained effects including hypothetical enlargement of the oxygen capacity of blood. In any case, the visible benefit of the third post-altitude positive phase is that it allows more active exploitation of competitive workloads within Final Stage Preparation for the target-event.

9.2.5. Non-conventional approaches to altitude training and exposure

It has been noted that since the 1968 Mexico City Olympics, the popularity of altitude training has increased continually. Hence, this preparation mode can now be termed conventional. In recent years modifications of altitude training have appeared and they can be considered non-conventional approaches to athlete preparation (Table 9.9).

Table 9.9.
Recent non-conventional approaches to altitude training

Approach	Brief description	Sources
Live High Train Low (LHTL)-natural conditions	Athletes live at altitude and perform their training at (or near) sea level conditions	Levine & Stray-Gundersen, 1997; Chapman et.al., 1998
Live High Train Low (LHTL)-artificial conditions	Athletes live and sleep in simulated altitude environment and perform their training at sea level	Rusko et al., 1995; Nummela & Rusko, 2000 a.o.
Training in a hypoxic chamber	Athletes train in artificial conditions of a hypoxic chamber	Terrados et al., 1988; Fuchs & Reiss, 1990 a.o.

Study and example. Twenty-two elite male and female runners lived and completed basic continuous training at altitude 2500m for 28 days. The intensive interval workloads were performed at altitude 1250m. This design resulted in a high increase of EPO concentration and significant increments of hemoglobin (8%) and erythrocyte mass (4%). After returning at sea level the athletes improved their running performance in 3000m (1%) and maximal oxygen uptake (3%). (Stray-Gundersen et al., 2001).

Despite the complexity of this approach it has been applied by several groups of athletes (mostly swimmers and runners), who found it practical, acceptable and promising.

The LHTL preparation approach in artificial conditions presupposes utilization of a specially created hypoxic living space (room, tent or even apartment), where lower oxygen content is combined with normal barometric pressure (normobaric hypoxia). The highest expectations from this approach pertain to the hematological factor: living at simulated altitude produces increased synthesis of EPO, hemoglobin and erythrocytes, which cause an increase of maximal oxygen consumption and aerobic performance. These suppositions have been supported in several studies (Mattila & Rusko, 1996; Rusko et al., 1999) but contradict the findings of other researchers (Piel-Aulin et al., 1998; Ashenden et al., 1999, inter alia). The other promising data relate to the potential benefits of simulated altitude exposure in anaerobic performances. A well-controlled study of high-level male 400m sprinters has shown significant superiority of ten days of simulated altitude exposure (16-17 hr a day) as compared to a conventional preparation program (Nummela & Rusko, 2000). These outcomes are consistent with the data of trained cyclists, who spent 8-10 hr at a simulated altitude of 2650 m, performed their usual training program and markedly improved their performance and maximal anaerobic ability (Roberts et al., 2003).

Study and example. Nineteen trained cyclists divided into three groups underwent a preparation program at LHTL and at sea level for 5, 10, and 15 days. They spent 8-10 hr at simulated altitude 2650 m and performed an habitual training program. Performance gains were evaluated through a 4-min maximal cycling trial. The benefit of LHTL mode was confirmed by remarkable gains of Mean Maximal Power Output (4%) and particularly by Maximal Accumulated Oxygen Deficit (10%) as compared with no gains induced by a conventional program. Interestingly, no differences were noted between the changes after 5, 10, and 15 days duration of training and exposure (Roberts et al., 2003).

These data demonstrate the beneficial development of anaerobic ability which is attributed to enhanced muscular buffer capacity. This was confirmed in another study of LHTL at simulated altitude (3000 m) and exposure duration of 23 days (Gore et al., 2001). At the same time the weaknesses of the artificial LHTL mode should also be considered. One can assume that living in a restricted artificial space may negatively affect athletes' emotional state, and the hematological benefits still seem dubious. However, even if these benefits are obtained it is hard to imagine that they can be maintained for two-three weeks until competition.

Training in a hypoxic chamber can be evaluated in two ways: 1) from the outcomes of numerous studies conducted over the last two decades; 2) from practical experience of supplemental hypoxic training accumulated mostly in Germany.

The first aspect can be illustrated by the findings of several studies that indicated positive training outcomes. The previously described evidence of cellular adaptation was obtained by training one leg in a hypoxic chamber while the second leg was trained at sea level conditions (Terrados et al., 1990). A number of studies were conducted with high-level athletes, who trained for different periods in a hypoxic chamber and didn't register any superior results when compared with control sea level groups in terms of hematological status and maximal oxygen consumption. However, they did record significant benefits in maximal power output and anaerobic capacity (Terrados et al., 1988; Meeuwsen et al., 2001; Hendriksen & Meeuwsen , 2003). In contrast to these, a number of other studies were carried out in which simulated altitude training did not elicit positive outcomes in aerobic endurance trials. These well-controlled studies did not reveal any benefits for training in hypoxic conditions, either in long-duration performance or in terms of hematological responses and maximal oxygen consumption (Hahn et al.,1992; Vallier et al., 1996; Karlsen et al., 2002). Apparently altitude simulated training enables athletes to enhance anaerobic capacity but fails to improve aerobic long-distance endurance.

The second aspect refers the practical experience of altitude-simulated training approved during the multi-year preparation of elite German athletes (Fuchs & Reiss, 1990; Reiss, 1998). The supplemental training in hypoxic chamber was incorporated in the annual preparation for various purposes (i) to provide rational pre-altitude preparation (see 9.2.4); (ii) to maintain the positive changes induced by previous altitude training camp; (iii) as a rehabilitation program after illnesses or injuries. Correspondingly different training protocols were developed. The repertory of training means included specific and semi-specific exercises performed on running treadmill, cycling, rowing and paddling ergometer; various simulative exercises; workloads for strength endurance and general conditioning. The integration of altitude-simulated training in the framework of annual preparation will be considered below (9.2.6).

The following summary will conclude consideration of the potential benefits and particularities of non-conventional approaches to altitude training (Table 9.10).

Table 9.10.
Summary of different factors and their expected using non-conventional approaches to altitude training

Factor	Expected effect	LHTL-natural	LHTL-artificial	Hypoxic chamber training
General ecological influence	Positive emotional impact; favorable response to mountain nature, clean and fresh air, lack of urban stressors, etc.	yes	no	no
Increased intensity of exercise	Earlier development of aerobic-anaerobic and anaerobic abilities	yes	yes	yes
Hematological changes	Increased hemoglobin, erythrocyte mass and oxygen capacity of the blood	yes	???	no
Cellular adaptation	Increased aerobic enzymes, myoglobin and muscular	no	no	yes

	capillarity			
Anaerobic capacity	Enhanced anaerobic performance via increased buffer capacity of muscles	yes	yes	yes

General ecological influence of altitude exposure refers to the factor in which influence on the emotional and neuro-physiological spheres is multilateral and, as the rule, highly positive. The exciting and magnificent beauty of mountains; clean, fresh, cool air; the lack of typical urban stressors like noise, transportation pollution, endless bustle etc. all positively affect recovery and behavior as a whole. All these benefits increase the effectiveness of LHTL under natural conditions. In contrast, LHTL under artificial conditions has the obvious disadvantage of prolonged exposure to a closed-in and limited living space. All of the non-conventional approaches considered have visible benefits when compared with traditional altitude camps with regard to unlimited (or less limited) employment of intensive exercises. Indeed, this is one of important reasons why these approaches and techniques were developed.
The hematological factor seems to be relevant for each of the approac hes. In fact its effect on LHTL in artificial conditions was not supported by the outcomes of several studies, and wasn't found with regard to training in hypoxic chamber. The latter has promising benefits for muscular cellular adaptation, which can hardly be expected following training in normo-baric conditions (LHTL modes). A stimulating effect on anaerobic capacity can be expected after each of the above non-conventional approaches.

9.2.6. Altitude training as a part of the annual preparation cycle

If attitude training is incorporated in a preparation program its placement in annual plan is very important. Following the first general principle of altitude training (9.2.1), preparation planning is very different for altitude or for sea level performances. The annual preparation plan for a target-competition at altitude is characterized by longer total duration of altitude exposure, relatively more prolonged altitude camps and scheduling the last altitude camp to immediately precede the target competition (Figure 9.8).

Insert Figure 9.8 about here

Figure 9.8. Exemplary annual plan of preparation directed to target-competition at altitude (based on Issurin & Vrijens, 1995): AC – altitude camp

It is worth noting that altitude camps encompass a part of the accumulation mesocycle when the training program is mostly extensive and does not exceed the anaerobic threshold level, while the second part of altitude exposure can include intensive and even severe exercises and belongs to the transmutation mesocycle.

Annual plans directed to target-competition at sea level can be compiled according to two different designs: (a) when the Final Stage Preparation (FSP) is relatively shorter and exploits the second positive phase of re-acclimatization after the last altitude camp: (b) when the FSP is more prolonged and exploits more delayed consequences of the altitude training program (Figure 9.9).

Insert Figure 9.9 about here

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Plan A is the more popular; it was widely used in the preparation of world-leading athletes from the former GDR (Pfeifer, 1987; Fuchs & Reiss, 1990) and the USSR (Suslov, 1983; Kaverin & Issurin, 1990). Plan B is less known and is not discussed in the available literature although it was successfully utilized many times in the preparation of top-level athletes (for instance: GDR road cyclists, USSR canoe-kayak paddlers, and others). The benefits of plan B are mostly methodic: the use of highly intensive workloads in a favorable re-acclimatization phase, participation in pre-target competition raises self-confidence levels and facilitates techno-tactical innovations. However, there is no evidence that potential physiological post-altitude benefits can be prolonged for a period of 36-45 days.

For a long time training experts have strived to rationalize annual preparation so that it will combine traditional and non-conventional altitude training approaches. An example of such a creative approach is the annual preparation of German 50 km walkers, who won silver and bronze medals in the 1988 Seoul Olympics (Figure 9.10).

Insert Figure 9.10 about here

The above diagram illustrates the annual training program, in which each of three altitude camps was combined with altitude-simulated training blocks in pre- and post-altitude periods. It could be suggested that such a combination made it possible:
(a) to facilitate acute adaptation at the beginning of each altitude camp because the athletes had experienced a pre-acclimatization program in hypoxic chamber;
(b) to prolong the ergogenic altitude effect of the preceding camp using altitude-simulated workloads;
(c) to diversify the sea level training program and attain higher training responses.

Interestingly, these successful German walkers took part in Olympic competition 19 days after the last altitude camp and this post-altitude program contained a thoroughly designed altitude-simulated training block. It can be suggested that further progress of altitude programs will include rational sequencing and a combination of traditional and non-conventional approaches to altitude preparation.

9.2.7. Guidelines to compiling an altitude preparation program

Despite the specificity and properties of different sports, general guidelines for compiling a preparation program containing altitude training can be proposed (Table 9.11). These guidelines refer to general principles (9.2.1), phases of altitude acclimatization (9.2.2) and post-altitude re-acclimatization (9.2.3), particularities of several training stage containing the altitude camp (9.2.4) and preparation design for the entire annual cycle (9.2.6).

Table 9.11.

General guidelines for compiling a preparation program containing altitude training camps

Operations	Comments
Developing proper concepts of athletes' preparation containing altitude training	The general purpose, number, duration, timing and location of altitude camps should be reasonably determined
Selecting appropriates athletes who will employ the altitude program	The individual reactivity of athletes with respect to the categories of “responders” and “non-responders” should be taken into consideration
Determining a general approach to planning the training stage containing the altitude camp	The training stage chart should be designed with respect to pre-altitude and post-altitude preparation phases
Selecting and facilitating appropriate means to monitor training responses at altitude	Ordering blood analyses, body weight measurements, HR monitors, blood lactate analyzers require special attention
Compiling a training program for pre-altitude, proper altitude and post-altitude preparation phases	The training program should consider individual variations in training responses and phases of acclimatization and re-acclimatization
Special care regarding proper nutrition and use of dietary supplements	Water balance, possible iron deficit and muscular catabolic responses should be given particular attention
Planning post-altitude trials and competitions	The sport-specific trials and competition program should relate to favorable states of post-altitude re-acclimatization
Implementing the program of pre-altitude, proper altitude and post-altitude program in each specific training stage	Individual training responses are monitored and used for current alterations of preparation
Retrospective analysis of training responses at altitude and post-altitude effects following entire annual cycle	Overall conclusions and recommendations for further preparation are required

The above guidelines do not address non-conventional approaches to altitude training, which are still not widely used. It is obvious that they can enrich the traditional repertory but it should be kept in mind that utilizing them demands sophisticated conditions and extensive additional knowledge.

Summary

The initial impetus to study altitude training and performance was fueled by the need to compete in high prestige events like the 1960 Winter Olympics and the 1968 Summer Olympics. The further development of altitude training has been oriented mostly towards preparation for sea level performances. Review of the current literature allows us to reconstruct the scenario of physiological changes during altitude acclimatization: human responses in the acute phase differ widely from those during more delayed periods of adaptation (Table 9.2). The current grasp of altitude training is contradictory: many exercise physiology textbooks declare that altitude training provides no benefits for sea level performances compared to proper conventional training while publications addressed to coaches consider altitude training as an efficacious and practice-proven tool to enhance high-performance preparation. This contradiction can be partly explained by the variety of individual training responses to altitude training, i.e., the individual predisposition of some athletes is more favorable to it. Nevertheless, the potential benefits of altitude training for the enhancement of sea level performances embrace: (i) improved oxygen delivery to muscles induced by higher oxygen-carrying capacity of blood; (ii) enhanced oxygen utilization within the muscle cells due to higher activity of aerobic enzymes and increased myoglobin content; (iii) increased anaerobic capacity via improved buffering capacity in muscles and blood.

The general principles of altitude training postulate the importance of a primary goal – (1) preparing athletes for altitude or sea-level performance, or using the altitude camp for active recovery and diversification; (2) selecting athletes who respond positively to altitude training; (3) compiling an altitude training program in accordance to phases of acclimatization; and (4) designing the post-altitude training program with respect to phases of sea level re-acclimatization.

Acclimatization at altitude is subdivided into three phases: the first one – acute acclimatization – is the most restricted for training capacity and its duration (3-7 days) strongly depends on each athlete's individual peculiarities. The second transition phase brings more favorable but unstable and less predictable responses. Its duration also varies by individual and lasts 3-5 days. The third stabilization phase allows athletes to perform a training program with large workloads almost without limitation. The general approach that is proposed is to compile a training program according to the phases of acclimatization (Table 9.6). Similarly, post-altitude preparation is affected by phases of sea-level re-acclimatization and this determines favorable periods for competitions, namely: the intervals between days 14-28, and between days 36–46.

Special attention is given to compiling the training cycle containing an altitude camp. Usually the first part of an altitude program consists of aerobic medium intensity exercises, corresponding to the content of the accumulation mesocycle. The second part of altitude camp can include highly-intensive aerobic-anaerobic and anaerobic exercises which are typical of the transmutation mesocycle. High performance can be planned for the periods between days 14-28, and between days 36–46. Correspondingly, the training stage can be shorter or longer. When the training concept is intended to exploit the post-altitude ergogenic effect, the annual cycle includes two-three training stages with altitude camp.

In addition to traditional altitude training where athletes live and train at the same elevation, several non-conventional approaches have developed: (1) athletes live at altitude but train lower; (2) athletes live at altitude-simulated conditions and train at sea level; (3) athletes live at sea-level and train in altitude-simulated conditions. All of these original techniques have their own advantages and disadvantages (Table 9.10) and can be creatively implemented in athletes' preparation.

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Glossary

aerobic endurance (capacity) – Ability to sustain fatigue in exercises where energy supplied with oxygen
anaerobic glycolitic endurance (capacity) - Ability to sustain fatigue in exercises where energy predominantly supplied with anaerobic glycolitic reactions
anaerobic threshold - The level of effort where lactate levels begin to rise.
blood Lactate - Physiological indicator of glycolisis activation or anaerobic metabolism.
blood urea - Physiological indicator of metabolic fatigue and metabolic recovery.

catecholamines (adrenaline and noradrenaline) – Hormones produced by the adrenal medulla serving for rapid activation of metabolic reactions during excitation, physical effort and emotional tension.

cardiac output - The volume of blood pumped by the heart in liters/minute.

conjugated effect exercises - Exercises that combine work on motor ability and technical skill.

cortisol – Hormone that controls metabolism of carbohydrates and fats, acts as an anti-inflammatory agent and stimulates breakdown of protein.

creatine phosphokinase (CPK) - Blood enzyme that reflects the level of muscle tissue breakdown and serves as an indicator of protein metabolism

creatinphosphate – An energy-rich substance that plays crucial role for energy providing of short-term highly intensive exercises.

detraining – Decrease of functional capabilities of athlete due to insufficiency of corresponding training stimuli.

erythropoietin (EPO) - A hormone, produced by the kidney, which stimulates the bone marrow to produce red blood cells.

fartlek - The term that usually is used for describing a wide spectrum of non-uniform continuous exercises

funnel effect - Reduction of the targeted areas accessible to training stimuli with the increase of athletes' qualification.

Galvanic Skin Response (GSR) – Psycho-physiological indicator of emotional excitation

glycogen – The carbohydrates storage located in muscles and liver.

heritability - Characteristics of the degree of genetic determination of the several traits.

hypoxia – A reduced availability of oxygen to athlete's tissues.

key-exercise (or key-task) - The main meaningful element (drill, fight or match) of single workout.

key-workout - The most important developing workout, which is focused on the current main training directions.

.***maximal anaerobic glycolitic power*** – Maximal amount of work per minute attained in exercise where energy predominantly supplied with anaerobic glycolitic reactions.

maximal oxygen consumption (maximal aerobic power) - The maximum amount of oxygen that an individual can consume in a defined period of time.

mesocycles-blocks:

accumulation mesocycle – Employed to develop basic motor and technical abilities and enlarge motor potential of athlete.

transmutation mesocycle – Employed to transmute the increased generalized motor abilities into event-specific athletic preparedness.

realization mesocycle – Conducted for attainment of full restoration and event-specific readiness for forthcoming trial or competition.

microcycles:

adjustment – Devoted to initial adaptation to appropriate workloads.

loading – Devoted to fitness development; the most widely used type of microcycle.

impact – Microcycle utilizing extreme training stimuli.

pre-competitive – Devoted to immediate preparation for forthcoming competition.

competitive – Microcycle where athlete take part in competition.

restoration – Devoted to active recovery of the athlete.

modeling - The way and method to simulate the athlete's state, athletic performance and training process in formalized descriptions, logistic schemes, computer programs and adequate practical tasks.
muscle buffering capacity – The ability of muscles to tolerate the acid that accumulates in them during anaerobic workloads.
***overload principle* -** Postulates that fitness gain requires a load (stimulus) magnitude that exceeds the accustomed level.
responders (high, medium, and low) – The athletes, which manifest respectively high or medium, or low response to training stimuli.
sensitive periods - The periods in long-term preparation of the young athlete when he/she is more trainable to certain motor ability than in other times.
somatotype - Characteristics of body linear, broad and fatness dimensions in human body.
sport giftedness - Predisposition and higher trainability to certain athletic activity, which are referred to genetically transmitted properties of individual.
sport talent – Optimal combination of psycho-physiological, anthropometric and mental properties of individual that allowed him/her to attain the sport excellence.
stretch-shortening cycle – Muscle action consisting of eccentric (stretch) and concentric (shortening) phases.
supercompensation cycle – Sequence of physiological reactions on single or series of workloads following to attainment of higher than pre-load level of fitness.
targeted ability – The ability (physical or technical) upon which training workload has an effect.
testosterone – The predominant male sex hormone.
trainability – The athletes' feature to react positively to training stimuli
training cycles:
microcycle – Small training cycle embracing a number of training days.
mesoocycle – Medium size training cycle comprising of number of microcycles.
macrocycle – Big training cycle embracing a number of mesocyces.
annual cycle - Big training cycle embracing the preparation during one year.
quadrennial (Olympic) cycle – Training cycle comprising of four annual cycles.
training effects – Changes of athlete's state induced by training, namely:
acute effect - Changes in body state that occur during the exercise.
immediate effect – Changes in body state resulting from a single workout or/and single training day.
cumulative effect - Changes in body state and level of motor/technical abilities resulting from a series of workouts.
delayed effect - Changes in body state and level of motor/technical abilities obtained over a given time interval after a specific training program.
residual effect - Retention of changes in body state and motor abilities after the cessation of training beyond a given time period.
training means - Refers to all drills involved in the program.
training block - A training cycle of highly concentrated specialized workloads.
training periodization - The purposeful sequencing of different training units and cycles so that the athlete can attain the desired state and the planned results.
transfer of training results – Gain of performance achieved in not trained exercise.