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New Horizons for the Methodology and Physiology of Training Periodization

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Abstract

The theory of training was established about five decades ago when knowledge of athletes' preparation was far from complete and the biological background was based on a relatively small amount of objective research findings. At that time, traditional 'training periodization', a division of the entire seasonal programme into smaller periods and training units, was proposed and elucidated. Since then, international sport and sport science have experienced tremendous changes, while the traditional training periodization has remained at more or less the same level as the published studies of the initial publications. As one of the most practically oriented components of theory, training periodization is intended to offer coaches basic guidelines for structuring and planning training. However, during recent decades contradictions between the traditional model of periodization and the demands of high-performance sport practice have inevitably developed. The main limitations of traditional periodization stemmed from: (i) conflicting physiological responses produced by 'mixed' training directed at many athletic abilities; (ii) excessive fatigue elicited by prolonged periods of multi-targeted training; (iii) insufficient training stimulation induced by workloads of medium and low concentration typical of 'mixed' training; and (iv) the inability to provide multi-peak performances over the season. The attempts to overcome these limitations led to development of alternative periodization concepts. The recently developed block periodization model offers an alternative revamped approach for planning the training of high-performance athletes. Its general idea proposes the sequencing of specialized training cycles, i.e. blocks, which contain highly concentrated workloads directed to a minimal number of targeted abilities. Unlike the traditional model, in which the simultaneous development of many athletic abilities predominates, block-periodized training presupposes the consecutive development of reasonably selected target abilities. The content of block-periodized training is set down in its general principles, a taxonomy of mesocycle blocks, and guidelines for compiling an annual plan.

Sport science is widely held to be the major contributor to progress in sport, and in particular to the enhancement of athletic training. Its general theory sets out and summarizes the most meaningful basic assumptions regarding the essence, terminology, major effects and scientific background for training athletes.

Training periodization is definitely one of the most practically oriented branches of training theory. It was established in general in the 1960s and was initially based on the experience of high-performance sport in the former USSR and physiological surveys published by prominent Soviet scientists at that time.[1-4] A little later, training periodization was conceptualized,[5] republished in many countries[6-9] and took on the status of a universal and monopolistic background for training planning and analysis.

Certainly, the continued evolution of sport and sport science has contributed to an enormous accumulation of knowledge, evidence and training technologies. Nonetheless, the traditional model of periodization as established about five decades ago has not changed much since then. During this time, and especially in recent years, alternative approaches to training design have appeared, mostly in professional reports and coaches' magazines, and have been subjected to little, if any, serious scientific consideration. The purpose of this paper is to review training periodization in the light of the outcomes of previous and recent studies of the traditional model and up-to-date versions of training design.

1. Traditional Model of Periodization

As athletic training becomes more strenuous and professional, the need for a scientific background for conscious planning becomes more desirable. Thus, 'training periodization' met the expectations of practice: it was described as the purposeful sequencing of different training units (long duration, medium duration and short-term training cycles and sessions) so that athletes could attain the desired state and planned results. This section introduces a brief history of training periodization and its basic tenets, which underlie the popular traditional model used worldwide.

1.1 History of Training Periodization as a Scientific Problem and Coaching Concept

1.1.1 Precursors of Periodization Training in Ancient Rome and Greece

The history of ancient medicine and philosophy provides us with memorable milestones of training theory. These pieces of human creation include the names of great ancient thinkers such as Galen and Philostratus. The famous Roman physician and philosopher Galen (Claudius Aelius Galenus, second century AD) in his treatise *Preservation of Health* proposed the original categorization of exercises, which can be qualified as the precursor of contemporary periodization for strength training.[10] His exercises with sequences from "exercises with strength but without speed" to developing "speed apart from strength and force" and, finally, to "intense exercises combining strength and speed,"[11] astonish us by their logic and creativity, although they can be questioned in the light of contemporary knowledge. Another example of annual periodization can be found in the essay *Gymnasticus* of the prominent ancient Greek scientist Philostratus, 'the Athenian', who also lived in the second century AD.[12] His description of pre-Olympic preparation contains a compulsory 10-month period of purposeful training followed by 1 month of centralized preparation in the city Elis prior to the Olympic Games. This final part of the annual cycle resembles pre-Olympic training camps practiced by any national squads today. The guidelines set down by Philostratus, which sequence small, medium and large workloads within a 4-day training cycle, can serve as a brilliant illustration of the ancient approach to short-term planning.

1.1.2 Contemporary Stage of Developing Training Periodization

The foundations of the contemporary theory of periodization were first proposed in the former USSR, where textbooks for coaches and physical education students called for the division of the entire preparation process into separate periods of general and more specialized training.[13] This separation into general preparation, encompassing training for cardiorespiratory fitness, general coordination and basic athletic abilities, and specialized preparation with a focus on sport-specific traits, remains till now. This general approach was adopted in most sports, and earlier textbooks on skiing,[14] swimming[15] and track and field[16] were written based on these commonly accepted approaches. In the 1950s, a number of physiological surveys were published.[1-4] At the same time, studies provided serious biological background support and a scientific basis for the guidelines. However, the first serious summary of up-to-date scientific and empiric concepts was compiled by Lev P. Matveyev,[5] making him the recognized founder of the traditional theory of training periodization. Actually, training periodization – meaning 'the subdivision of the seasonal programme into smaller periods and training cycles' – appears to be an important and indispensable part of training theory.

1.2 Basic Positions of the Traditional Model

The basic positions of the traditional theory of training periodization include: (i) a general elucidation of load and recovery in view of the supercompensation concept; (ii) general principles of periodized training; (iii) the hierarchy of periodized training cycles; and (iv) proposed variations of the annual cycle. Let us consider each of these positions.

1.2.1 Generalized Concept of 'Load-Recovery' Interaction

Perhaps the first scientifically based explanation of fitness enhancement was offered in the mid-1950s by Soviet biochemist Yakovlev,[2,17] who reported on the supercompensation cycle after a single workout. The phenomenon of supercompensation is based on the interaction between load and recovery (figure 1).

The supercompensation cycle is induced by the physical load, which serves as the stimulus for further reaction. The single load, which is considered the first phase of the cycle, causes fatigue and acute reduction in the athlete's work capability. The second phase is characterized by marked fatigue and a pronounced process of recovery; consequently, towards the end of this phase the

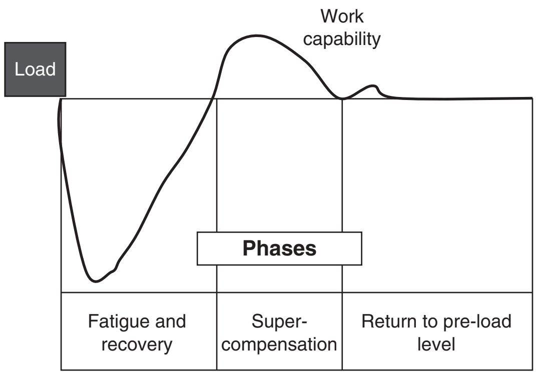

Fig. 1. The supercompensation cycle, showing the trend of work capability following a single load.[2]

athlete's work capability increases and reaches pre-load levels. During the third phase, work capability continues to increase, surpassing the previous level and achieving the climax, which corresponds to the supercompensation phase. In the fourth phase, work capability returns to the pre-load level.

This load-recovery pattern has been proven using the depletion and restoration of biochemical substances such as creatine phosphate[18,19] or glycogen.[20,21] A similar trend was noticed using various physiological estimates[22] and sport-specific tests.[23,24] Based on the supercompensation theory, Matveyev[25] proposed a general scheme of several-load summation. According to this scheme a number of workouts can be performed while the athlete is still fatigued, and the supercompensation effect can be induced following a specific training cycle but not a single workout. This position formed the foundation for compiling small training cycles (microcycles) and designing pre-competition training.

1.2.2 Principles of Periodized Training

A number of specialized principles were proposed by Matveyev[25] and popularized in further publications on training theory. One of the basic tenets determining the general concept of periodized training is the 'principle of cyclical training design'. This principle applies to periodic cycles in athletic training. Over a long period, the many components of long-term training repeat and return periodically. The rationales for this approach pertain to: an *habitual rhythm* of working days and vacation; the *cyclical character of adaptation* that presupposes periodical regeneration of adaptability; the *sharing of main tasks* that allows the development of general and sport-specific motor abilities, technical and tactical skills; and the *competition schedule*, which strongly determines the apexes of athletes' preparation and periodic changes in the training programme.

The principle of 'unity of general and specialized preparation' emphasized the importance of specific workloads during a long period of early season training, and the necessity of general conditioning workouts within the period of frequent competitions. It is worthy of note that this principle was claimed at a time when 'seasonal' impacts were much stronger than they are today. Such sports as skiing, skating, rowing, ice hockey and soccer were strictly determined by seasonal conditions. Correspondingly, stressing the linkage between general and specialized preparation was necessary for both methodical and organizational reasons.

Another meaningful principle called 'wave-shape design of training workloads' was postulated during the 1950s for short-term (weekly programme) and for long-term (annual cycle) planning design. This principle proclaimed the need to alternate days of high load and lower load, sequencing large, medium and small workloads. The physiological sense of this principle was supported by the outcomes of biochemical and physiological studies conducted at that time.[1-4] The findings of post-exercise recuperation showed that such sequencing of workloads facilitates the probability of favourable training responses and the prevention of excessive fatigue accumulation. Similarly, the medium-size waves in monthly training and large waves in the annual training plan were intended to refresh athletes' adaptability and avoid the monotony of repetitive training routines.

The 'principle of continuity' was postulated at a time when interruptions in training were relatively frequent and excusable. The principle claimed that such interruptions are very harmful biologically, pedagogically and organizationally.

It also proposed that breaks in training for recuperation and social needs should be thoroughly planned, whereas sporadic breaks should be totally excluded. Nowadays, with the majority of high-performance athletes training at professional and semiprofessional levels, the importance of this principle is still relevant although now it seems quite trivial.

1.2.3 Hierarchy of Periodized Training Cycles

As stated in the introduction, the general concept of periodized training was proposed in the 1960s and has been adopted by many generations of analysts and coaches (table I).

The upper level of the hierarchical periodized system belongs to multi-year preparation, where the Olympic quadrennial cycle is of particular importance. The next level of the hierarchy is represented by the macrocycles, which usually last 1 year but can be shortened to half a year and even less. The macrocycles are divided into training periods, which fulfil a key function in traditional theory: they divide the macrocycle into two major parts, the first for more generalized and preliminary work (preparatory period), and the second for more event-specific work and competitions (competition period). In addition, a third and the 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 blocks of the entire training system.

Table I. The hierarchical structure and content of periodized training cycles[5,6]

Preparation component and its duration	Content
Multi-year preparation (years)	Long-lasting systematic athlete training composed of 2-year or 4-year (quadrennial) cycles
Macrocycle (months)	Large size training cycle (frequently annual cycle) that includes preparatory, competition and transition periods
Mesocycle (weeks)	Medium size training cycle consisting of a number of microcycles
Microcycle (days)	Small size training cycle consisting of a number of days; frequently 1 week
Workout (h/min)	A single training session that is performed individually or within a group

Because the periods are the most meaningful components in the traditional theory, their particularities and content are clearly prescribed. The preparatory period programme should contain extensive, high volume, diversified exercises to develop mostly general physical and technical abilities, whereas the competitive period should be focused on more intensified, specialized exercises of reduced volume, including participation in competitions. The biological background of such a design presupposes a gradual enhancement of athletes' adaptability induced by increasing training stimulation.

1.2.4 Variations of the Traditional Annual Cycle Model

The earlier versions of periodized plans were oriented to macrocycles lasting an entire season. Such a planning approach can be defined as a 'one-peak annual plan'. In the early 1960s, such a design corresponded to many seasonal sports such as rowing, cycling, skating and skiing. The appearance of various sport facilities and the general progress of sport made it necessary to expand competitive practice. Thus, the one-peak annual design became insufficient and 'two-peak annual plans' were introduced. However, further progress in sport facilities, diversification of competitions and increased professionalism of training led to the elaboration of 'three-peak preparation models',[26,27] which became the last commonly recognized modification of traditional periodization (figure 2).

1.3 Major Limitations of Traditional Periodization

Although the traditional model proposes a sequencing of different targets (from general to specific; from extensive to more intensive work, etc.), the predominant methodical approach is predicated on the simultaneous development of many targeted abilities. For instance, preparatory period training for high-performance athletes in endurance, combat sports, ball games and aesthetic sports usually contains a programme for

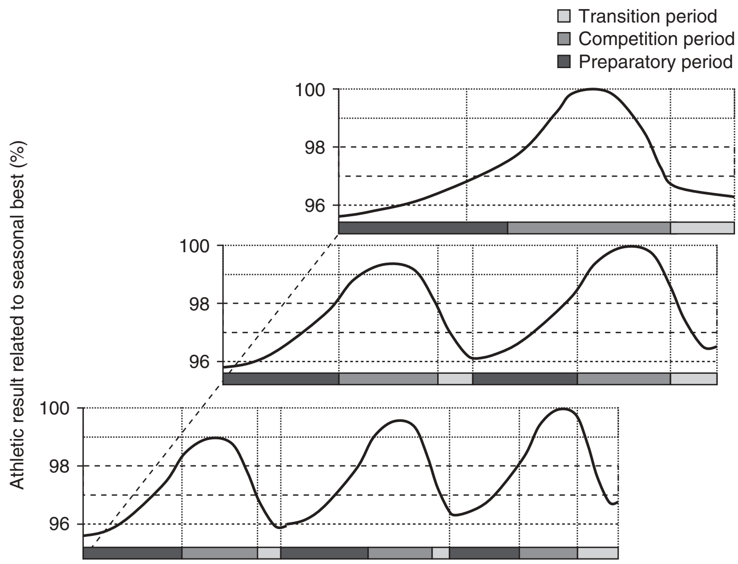

Fig. 2. One-peak, two-peak and three-peak annual cycles, displaying the annual trend of athletic results related to the seasonal best achievement.

the development of general aerobic ability, muscle strength and strength endurance, improvement of general coordination, general explosive ability and general speed, basic mental and technical preparation, mastery of the tactical repertory, treatment of previous injuries, etc. Each of these targets requires specific physiological, morphological and psychological adaptation, and many of these workloads are not compatible, causing conflicting responses. These disadvantages of the traditional model may be negligible for low-level athletes, where a complex mixed programme makes training more attractive and entertaining. However, for high-performance athletes the limitations of traditional periodization raise serious obstacles to further progress (table II).

Obviously, these limitations substantially decrease the quality of training. Unlike novices and medium-level athletes, who require relatively low training stimulation to progress, high-performance athletes enhance their preparedness and performance through large amounts of training stimuli that can hardly be obtained using traditional multi-targeted mixed training.

One additional drawback of the traditional model is its inability to enable athletes to participate successfully in many competitions. The traditional periodization proposes one-, two- and three-peak designs, where the annual cycle consists of one, two or three macrocycles.[24-26] However, even the three-peak design does not satisfy the international sport trend towards competitions throughout the year. The multi-peak tendency of modern top-level sport is in obvious contradiction to traditional periodization.[28] All of these circumstances and factors contributed to the search for alternative training approaches, which were offered by creative coaches and scientists and are considered below.

2. Alternative Models of Periodization

The initial impetus to reform traditional periodization first began among prominent coaches in different sports when they saw that the instructions for training management restricted their creativity and didn't allow their athletes to attain their highest achievements. Attempts to improve the traditional model were cosmetic in character at first; however, in the early 1980s, reformation tendencies became stronger. The most influential factors evincing this revision were the substantial changes occurring at that time in world sport and athletic training.

2.1 Factors Affecting the Revision of Traditional Periodization

A number of factors effected a reformation of the traditional training system and encouraged a search for alternative approaches. These factors included limitations of traditional periodization in terms of the concurrent development of several motor and technical abilities (table II), and dramatic changes in world sport in recent decades.

Evidently, the tremendous changes in world sport over recent decades had a strong influence on the evolution of the training process. Despite the uniqueness of each sport, these changes appeared to have an overall tendency worldwide, with a number of main characteristics.

- *An increase in the total number of competitions:*[24,44] correspondingly, their contribution to training stimuli has increased dramatically.
- *Financial motivation* of top athletes, which became much stronger than previously.
- *Closer cooperation and sharing* among world coaches, which led to enhancement of training quality and level of athletic performances.
- *The struggle against illegal pharmacological interventions*, which affected and which led to the prevention of such harmful technologies in high-performance sport.[45]
- *Implementation of advanced sport technologies* and training methods such as monitoring of heart rate, blood lactate, movement rate, etc.;[35,46] improvement of medical follow-up methods;[47,48] and elaboration of advanced training equipment and new materials.[49-51]

These advances, combined with increased sharing of successful planning approaches among coaches, have spurred tremendous progress in training methodology.

2.2 Periodization Charts in Team Sports

It has been widely acknowledged for some time that preparation planning in team sports differs drastically from planning routines in individual athletic disciplines. Several surveys of team sports report the adoption of periodized models of the traditional concept.[52,53] However, many recent publications declare that basing training programmes on the ‘classic model’ of periodization is counterproductive for most team sports.[54-56] The playing season for team sports like football, rugby, basketball, ice hockey, etc. lasts 20–35 weeks in Europe and North America.[56,57] It has been shown that a training design following traditional planning precepts leads to dramatic reductions in lean body mass,[42] maximal strength of relevant muscle groups,[58,59] maximal anaerobic power[60] and even maximal speed.[61]

Application of the traditional model is still realistic for junior and low-level athletes, whose competition phases are relatively short and can be considered similar to those of individual sports. However, to consider the playing season

Table II. Major limitations of traditional periodization for training high-performance athletes

Factor	Limitations
Energy supply	Lack of sufficient energy supply for concurrent performance of diversified workloads[28-30]
Cellular adaptation	Training consequences such as mitochondrial biogenesis, synthesis of myofibril proteins and synthesis of anaerobic enzymes presuppose separate pathways of biological adaptation[31-33]
Post-exercise recovery	Because different physiological systems require different periods of recuperation, athletes do not get sufficient restoration[34-36]
Compatibility of various workloads	Exercises combining various modalities often interact negatively due to energy deficit, technical complexity and/or neuromuscular fatigue[37-39]
Mental concentration	Performance of stressed workloads demands high levels of mental concentration that cannot be directed at many targets simultaneously[40,41]
Sufficiency of training stimuli for progress	Sport-specific progress of high-level athletes demands large amounts of training stimuli that cannot be obtained by concurrent training for many targets[24,42]
Competitive activity	Inability to provide multi-peak preparation and successful performances during the entire annual cycle[37,43]

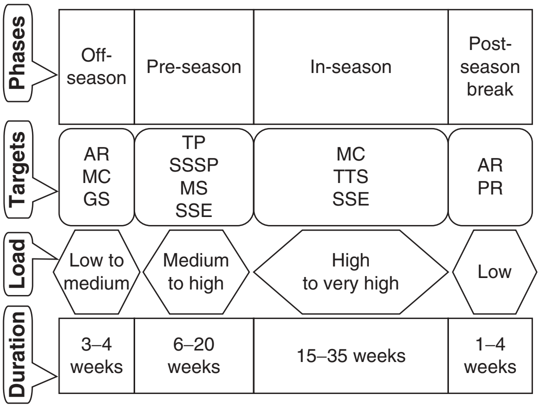

Fig. 3. Schematic presentation of an annual preparation chart in team sports.[40,41,49] **AR** = active recovery; **GS** = general strength; **MC** = metabolic conditioning; **MS** = maximal speed; **PR** = psychological recovery; **SSE** = sport-specific endurance; **SSSP** = sport-specific strength and power; **TP** = technique perfection; **TTS** = techno-tactical skills.

of qualified athletes from the viewpoint of traditional periodization leads to an absurd situation in which the climax phase of annual preparation consists of 20–30 competitive microcycles. In this situation the generalized concepts of peaking and tapering make no sense. Perhaps this is one of the reasons that many experts in team sports avoid utilizing traditional terms such as preparatory and competition periods and use team sport-specific terms like ‘off-season’, ‘pre-season’ and ‘in-season’ training.[56,62]

A general presentation of the annual cycle for qualified players specifies the relevant phases of their preparation in terms of duration, dominant training targets and load level (figure 3). Of course, because of the variation among team sports, national competition calendars and the particularities of training for different age groups, it is impossible to compile a universal chart model. It can be suggested that training in off-season and pre-season phases can resemble training in the traditional periodization approach.[56] A careful inspection of the preparation programmes proposed for high-performance players reveals that even this is highly restricted. Indeed, the traditional model facilitates the acquisition of an optimal combination of all sport-specific abilities to ensure peak performances for a limited number of days, whereas rational preparation planning in team sports presupposes the maintenance of sport-specific preparedness over 4- to 8-month periods.

From a physiological viewpoint, the importance of rationally periodized training in team sports cannot be underestimated. The long playing season with its large number of stressful games frequently leads to harmful consequences such as pronounced catabolic responses,[61,63] musculoskeletal disorders and a high incidence of injuries.[56] Reasonably structured training that avoids conflicting physiological responses facilitates the beneficial maintenance of sport-specific preparedness and prevents a decline in relevant physiological capabilities and traits.[62,64,65]

2.3 Linear and Non-Linear Periodization

Attempts to reform and rationalize traditional periodization were undertaken by several researchers and training analysts. Their intention was to update the traditional model and to distinguish between so-called ‘linear’ and ‘non-linear’ periodization.[66,67] Proponents of the revised version proceeded from the assumption that traditional periodization postulates a gradual progressive increase in intensity and can therefore be termed a linear model. In contrast, the non-linear model offers drastic variations of intensity within the weekly and daily programme. This ‘variation factor’ was especially emphasized in the term ‘undulating periodization’[66] that was attached to the non-linear model. In reality, traditional periodization does not ignore – and even requires – wave-shaped fluctuations of workloads within the single-day, micro- and mesocycles; it also does not restrict the amplitude of these variations. Moreover, the principle of wave-shape training design emphasizes the importance of this variation factor (see section 1.2.2). This inconsistency of the proposed concept was noted by Stone and co-authors.[68,69] Apparently the traditional model is both ‘non-linear’ and ‘undulating’, whereas the ‘linear model’ looks extremely artificial and contradicts general physiological and methodic demands. The opponents of this concept correctly declared that the use of terminology such as 'linear' and 'non-linear' is misleading.[70] The author completely supports this position and assumes that such is the case when an attempt is made to attach non-traditional terms to well known traditional training approaches.

2.4 Non-Traditional Models of Training Design

As noted in sections 2.1, 2.2 and 2.3, the alternatives to traditional periodization models were created both by practitioners (prominent coaches and athletes) and scientists. This section presents examples of such alternatives.

2.4.1 Annual Performance Trends of Great Athletes

One of the typical characteristics of contemporary high-performance sport is multi-peak preparation for attaining excellent results throughout a season, and not two to three times as in traditional periodization. The examples of world-leading athletes from individual sports demonstrate incredible stability in peak performances at relatively short intervals (14–43 days) between peaks.[44,71] The diagram in figure 4 displays the annual performance trend of one of the greatest track and field athletes, Sergei Bubka (USSR [since 1991 Ukraine]), who earned an Olympic gold medal in 1988 and five World Championship gold medals in pole vault. His world record (614 cm) stands to this day.

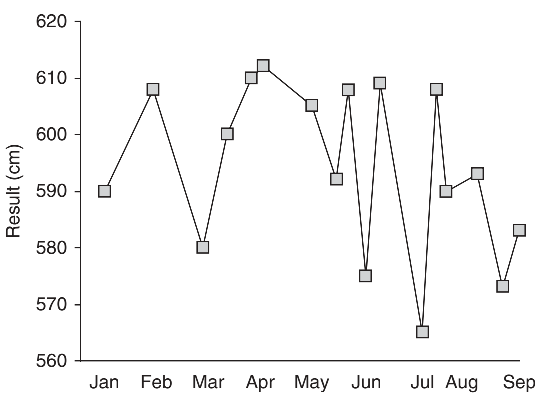

Fig. 4. The annual pole vault performance trend of Sergei Bubka in the 1991 season.[28]

The graph indicates six peaks where the athlete obtained 12 results higher than 590 cm that corresponds to the result of the winner at the 2009 World Championship. A brief analysis of this athlete's annual performance trend reveals the following characteristics about his personal model of periodized training.

During a period of about 250 days, Sergei Bubka took part in a long series of competitions; this period was preceded by pre-season preparation that lasted about 3 months, during which time he did not take part in official tournaments. During a period of 9 months the athlete took part in a number of competitions and his results ranged from 92% to 100% of personal best; this extensive competitive practice provided the athlete with very strong training stimuli. The intervals between peak performances varied from 12 to 43 days (usually 22–27); this time span was sufficient for active recovery but absolutely unrealistic in order to fulfil any periods of the generalized preparation as proposed in traditional periodization.[24-27] It is obvious that this long time span (9 months) during which the athlete successfully competed at the world-class level cannot be subdivided into traditional preparatory and competition periods. On the other hand, the athlete's basic abilities (maximal strength, aerobic regeneration capacity) needed to be maintained at a sufficient level. Therefore, the appropriate short-term training cycles for basic abilities and recovery were incorporated into his programme.

Of course, Sergei Bubka is a unique athlete, but the example of his preparation is typical for contemporary high-performance sport, as can be seen by similar examples for other great athletes.[44,71] Obviously, the traditional scheme does not provide such a multi-peak preparation design, and great athletes and their coaches had to find their own periodization models as alternatives to the traditional approach.

2.4.2 Concentrated Unidirectional Training Plans

The concept of concentrated unidirectional training was proposed by Verchoshansky[72] for preparation in the power disciplines. This training design was tested during preparation of high jumpers, who executed a 4-week mesocycle of highly concentrated strength training followed by a restitution mesocycle lasting 2 weeks during which the athletes focused on perfecting technical skills, speed exercises and general fitness training. During the first loading mesocycle the relevant strength indicators decreased gradually; however, during the subsequent restitution mesocycle these indices increased to a higher level than had been recorded prior to the training programme. The author recommends repeating this combination of loading and restitution mesocycles during the annual cycle. The gains obtained in strength and power can be explained as part of the long-lasting delayed effect (LLDE), which is a subject deserving special consideration. The author claims that LLDE is conditioned by highly concentrated, large-volume workloads during the first phase, and reduced workloads in the second phase.[73] The concept presupposes that the lower the decrease the functional indices move in the first phase, the higher they will increase in the second phase; the duration of the first phase varies in duration from 4 to 12 weeks. Correspondingly, a similar time span is expected for positive after-effects following this concentrated training.

The idea of concentrated unidirectional training has been discussed extensively in the literature,[74-76] and was transferred from the power disciplines to other sports, specifically in a long-term study of qualified adult basketball players.[76] The annual cycle was subdivided into two macrocycles lasting 23 and 19 weeks. Each macrocycle consisted of three stages: (i) a loading phase of strength and power workloads (8 and 3 weeks, respectively); (ii) a restitution phase (2 and 3 weeks, respectively); and (iii) a competition stage, where the players took part in regional championship (13 weeks in both cases). The experimental group, which had no control counterpart, significantly enhanced results in power tests, and their dynamics corresponded to the trend proposed by the LLDE concept. Unfortunately, the authors did not report the results of the athletes in the basketball tournament, which was definitely the team's first priority. It can be suggested that a reduction of functional background during prolonged loading phases can have a deleterious effect on sport-specific preparedness and reduce the effectiveness of team practice.

In conclusion, it is worth noting that performances in most sports require manifestations of multiple physical and technical abilities. This definitely restricts application of the unidirectional training concept to the actual design of preparation programmes.

3. Block Periodization as an Alternative Approach to High-Performance Training

In the early 1980s, the term 'training blocks' became popular and widely used among high-performance coaches. Of course, it was not conceptualized initially and was found mostly in coaches' jargon. Nevertheless, in its most comprehensive connotation it referred to "a training cycle of highly concentrated specialized workloads."[37] Such cycles contain a large volume of exercises directed at a minimal number of targeted abilities. As a planning approach, training blocks seemed an alternative to traditional multi-targeted mixed training, which was under extensive criticism by creative coaches and researchers. Gradually, successful attempts to implement training blocks led to the appearance of a preparation system called 'block periodization'. As a new methodological approach, block periodization has been dealt with in several publications, which are considered below.

3.1 Earliest Efforts to Implement Block Periodization

It can be suggested that the first attempts to implement training blocks in practice were not documented and survive mostly from anecdotal reports. However, at least three successful experiences in block-periodized training were systematized and published.

One of the pioneers in reforming traditional periodization was Dr Anatoly Bondarchuk, who coached the gold, silver and bronze medal winners in the hammer throw at the 1988 and 1992 Olympic Games and many other top-level athletes. The system he created comprised three types of properly specialized mesocycle blocks: *developmental blocks*, in which workload levels gradually increase to maximum; *competitive blocks*, in which the load level is stabilized and athletes focus on competitive performance; and *restoration blocks*, in which athletes utilize active recovery and prepare for the next developmental programme. The sequencing and timing of these blocks depends on the competition schedule and on individual athlete's responses.[77,78]

A similar block-periodized model was proposed and implemented in the preparation of top-level canoe-kayak paddlers.[79] Three types of mesocycle blocks were elucidated: *accumulation*, which was devoted to developing basic abilities such as general aerobic endurance, muscle strength, and general 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 race modelling, obtaining maximal speed and recovery prior to the forthcoming competition. These three mesocycles were combined into a separate training stage, lasting 6–10 weeks, which ended with competition; a number of training stages formed the annual macrocycle. The radically reformed preparation programmes resulted in outstanding performances of the USSR national canoe-kayak team, who earned three gold and three silver medals in the 1988 Seoul Olympic Games and eight and nine gold medals in the World Championships of 1989 and 1990, respectively.[80]

One more successful experiment with this approach was conducted by world-renowned swimming expert Gennadi Touretski, who coached Alexander Popov (Russia) – five-time Olympic Champion and multiple World and European champion – and Michael Klim (Australia) – two-time Olympic champion, multiple World champion and medal winner. Touretski subdivided the annual cycle into a number of stages lasting 6–12 weeks, where each one comprised four training blocks in the following sequence: *preparation, general, specific* and *competitive*.[81] Later, the author modified this taxonomy and called them the *general block*, which focused on aerobic and varied coordinative workloads, the *specific block*, which was devoted to developing event-specific energetic mechanisms and competitive speed, and the *competitive block,* which corresponds to what today is commonly called 'tapering', and culminates with competition.[82] This stage is usually followed by a short recovery cycle.

Despite the obvious uniqueness of each sport in which these experiments were undertaken, the principal methodological demands of training were almost identical:

- The authors created training blocks in which workloads focus on a minimal number of targets.
- The total number of proposed blocks is relatively small (three to four). This is in contrast to the traditional theory, in which the mesocycle taxonomy includes 9–11 types.[6,24-27]
- The duration of a single mesocycle block ranges from 2 to 4 weeks, which allows the desired biochemical, morphological and coordinative changes to occur without excessive fatigue accumulation.
- The joining of single mesocycles forms a training stage: their correct sequencing is beneficial to competitive performance, i.e. peaking.

3.2 Scientific Concepts Affecting the Block-Periodized Model

At least two contemporary scientific concepts had a distinct impact on the establishment of the block periodization preparation system: the *cumulative training effect* and the *residual training effect*.

3.2.1 Cumulative Training Effect

In terms of competitive sport, the cumulative effect of long-term training is the primary factor that, to a great extent, determines an athlete's success. The cumulative training effect can be expressed as "changes in physiological capabilities and level of physical/technical abilities resulting from a long-lasting athletic preparation."[37]

Correspondingly it can be reflected by two groups of indicators: (i) physiological and biochemical variables, which characterize changes in the athlete's biological status; and (ii) variables of sport-specific abilities and athletic performance, which characterize changes in the athlete's preparedness.

The functional limits of the various physiological systems cannot be increased to the same extent, and different physiological indicators of cumulative training effects vary within their appropriate range. The most pronounced changes can be obtained in aerobic abilities. More specifically, purposeful endurance training can dramatically increase aerobic enzymes, the number of mitochondria, myoglobin content and muscle capillarization.[83,84] 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 and creatine phosphate storage, with increases that are relatively small even when training is highly intensive.[85,86]

Cumulative training effects attained in various sport-specific abilities strongly depend on changes in the physiological variables mentioned above. Thus, the improvement rate in aerobic endurance disciplines is much higher than in events demanding maximal anaerobic power and capacity. Gains in maximal strength are determined by changes in the musculoskeletal system and the neural contraction mechanism.[87]

Managing the cumulative training effect presupposes the planning and regulation of workloads over relatively long periods, which involves competence in training periodization. The concept of cumulative training effect is extremely important for both traditional and block periodization models, although the usual trend of physiological and sport-specific variables differs in each alternative system. Multi-targeted mixed training, typical of the traditional model, causes an increase in basic athletic abilities in the preparatory period followed by their decline in the subsequent competition period, whereas the sport-specific abilities are suppressed in the prolonged preparatory period and increase during the competition period. The block periodization system with its multi-peak preparation allows athletes to maintain both basic and sport-specific abilities in a relatively narrow range during the entire season.[71,77]

3.2.2 Residual Training Effect

The residual training effect concept is relatively new and is less known than other types of training outcomes. Long-lasting training is intended to develop many motor abilities, which remain at a heightened level for a given period after training cessation. This retention belongs to another special type of training effect called the 'residual training effect', which can be characterized as "the retention of changes induced by systematic workloads beyond a certain time period after the cessation of training."[37]

The general approach to 'training residuals' induced by 'residual effects of training' was conceptualized initially by Brian and James Counsilman,[88] and focused mainly on the long-term aspects of biological adaptation. They logically 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 very important. However, for designing training programmes, short-term training residuals are of primary importance.

The phenomenology of the residual training effect is closely connected with the process of de-training, which may occur selectively according to specific abilities when they are not stimulated by sufficient training.[89-91] When training is designed in the traditional manner and many abilities are developed simultaneously, the risk of de-training is negligible because each target (given physical or technical abilities) receives some portion of the stimuli. However, if these abilities are developed consecutively, as proposed by the block periodization system, the problem of de-training becomes important. Indeed, if an athlete develops one ability and loses another one at the same time, the coach should take into account the duration of the positive effect of a given type of training after its cessation and how fast the athlete will lose the attained ability level when he/she

Table III. Factors affecting the duration of short-term training residuals[37,88,92,93]

Factor	Influence
1. Duration of training before cessation	Longer training causes longer residuals
2. Load concentration level of training before cessation	Highly concentrated training compared with complex multi-component training causes shorter residuals
3. Age and duration of sport career of athletes	Older and more experienced athletes have longer residuals
4. Character of preparation after cessation of concentrated training	Use of appropriate stimulatory loads allows prolonged residuals and prevents fast de-training
5. Biological nature of developing abilities	Abilities associated with pronounced morphological and biochemical changes like muscle strength and aerobic endurance have longer residuals; anaerobic alactic and glycolitic abilities have shorter residuals

stops training for it. In other words, the coach has to know the residual effect of each type of training. The duration of training residuals varies depending on several methodological and physiological factors (table III).

It can be concluded that the prediction, evaluation and programming of cumulative and residual training effects appear to be meaningful and even indispensable components of block-periodized preparation.

3.3 Basic Positions of Block-Periodized Training

The basic positions of block-periodized training contain: (i) general principles; (ii) a taxonomy of mesocycle blocks; and (iii) guidelines for compiling an annual plan.

3.3.1 Basic Principles

The principles articulate the general idea of block periodization and summarize the outcomes of previous studies (table IV).[71,93-95]

The first and most crucial basic principle calls for a high concentration of training workloads within a given block. This means directing a large number of exercises and tasks to selected target abilities while others are not subjected to training stimulation. Of course, such a highly concentrated training programme is possible only for a minimal number of athletic abilities. In reality this leads to the allocation of 60–70% of the entire time budget to developing two to three targets, with the remaining time spent on restoration, warming up and cooling down. This important feature is declared in the second principle, which postulates a minimization of the number of target abilities within a single block (the alternative is complex mixed training in which many abilities are developed simultaneously). Furthermore, in a majority of sports, the number of decisive sport-specific abilities exceeds the number of abilities that can be trained simultaneously in a block with highly concentrated workloads. Thus, the third principle proposes that consecutive development is the only possible approach for training design in a block periodization system. Finally, the fourth principle demands implementation of an appropriate taxonomy of mesocycle blocks, which allows for structuring the preparation and compiling block-periodized programmes (see section 3.3.2). Therefore, medium-sized training cycles, called mesocycle blocks, are the most prominent embodiment of the block periodization concept in general.

3.3.2 Taxonomy of Mesocycle Blocks

It is easy to see that the proposed general principles lead ultimately to a taxonomy of mesocycle blocks, which serves the practical needs of compiling training programmes.

The ‘taxonomy of mesocycle blocks’, as already mentioned, is formed from three specialized types: (i) accumulation, (ii) transmutation, and (iii) realization. The first type is devoted to developing basic abilities such as general aerobic endurance and cardiorespiratory fitness, muscular strength and basic coordination. This mesocycle is characterized by relatively high volume and reduced intensity of workloads. Its duration varies from 2 to 6 weeks. The second type focuses on sport-specific abilities like special (aerobic-anaerobic or glycolitic) endurance, strength

Table IV. Basic principles of block periodization training[94,95]

Basic principles	Comments
High concentration of training workloads	Provides sufficient training stimulation for high-performance athletes
Minimal number of target abilities within a single block	Necessary to provide highly concentrated training stimulation
Consecutive development of many abilities	Usually the number of decisive abilities exceeds the number of abilities developed within a single block
Compilation and use of specialized mesocycle blocks	Specialized mesocycle blocks – i.e. accumulation, transmutation and realization – form the content of block periodization training

endurance, proper technique and tactics; this is the most exhausting training cycle and usually lasts about 2–4 weeks. The third type is intended to restore the athletes and prepare them for the forthcoming competition. It contains drills for modelling competitive performance and a sport-specific programme for quick active recovery. This ranges from 8 to 15 days.[95]

Joining three mesocycle blocks forms a single training stage that concludes with a specific competition. Unlike traditional periodization, in which the mixed training programme is intended to develop many abilities, the consecutive development of targeted abilities typical of block periodization produces training stimuli for several functions, while the other abilities decrease. In this view, the duration of residual training effects becomes of primary importance. The correct sequencing of the mesocycles within the training stage makes it possible to obtain ''optimal superposition of residual training effects'',[37] so as to allow competitive performance at a high level for all motor and technical abilities. This possibility arises because the training residuals of basic abilities last much longer than the residuals of more specific abilities, while the residuals of maximal speed and event-specific readiness are the shortest.[93,94] Thus, the total length of a single training stage ranges from 5 to 10 weeks, depending on competition frequency and sport-specific factors.

3.3.3 Compiling an Annual Cycle

Based on the above, designing an annual cycle can be viewed as a sequence of more or less autonomous stages, where similar aims are attained by means of partially renewed and qualitatively improved training programmes. 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 programme 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 stages. The typical annual cycle of block-periodized training is shown in figure 5.

The temporal structure of the annual plan is formed first of all by the chronology of the training stages. These stages are determined by the schedule of mandatory and targeted competitions and by the possible duration of several mesocycle blocks. Thus, training stage duration varies from 3 months (usually in early season) to 25 days (usually late in the season, depending on the frequency of mandatory competitions). Based on the general demands of the training stage chronology, additional competitions, training camps and medical examinations can be initiated.

Generally speaking, when coaches compile annual plans they face a dilemma: the liberal 'easy' plan will not lead to success, but the strenuous ambitious programme can engender excessive fatigue and be followed by failure. Viewed in this way, the block-periodized design has obvious benefits. Because of the similarity of sequential stages, coaches can formulate the plan of subsequent blocks based on feedback from the previous stage of training. The most stressful phases of work – i.e. the transmutation mesocycles – can be shortened, lengthened or modified after changes in the athletes' responses. In the lead-up to a targeted competition, coaches can review the tapering programme two to three times and approve the most favourable version.

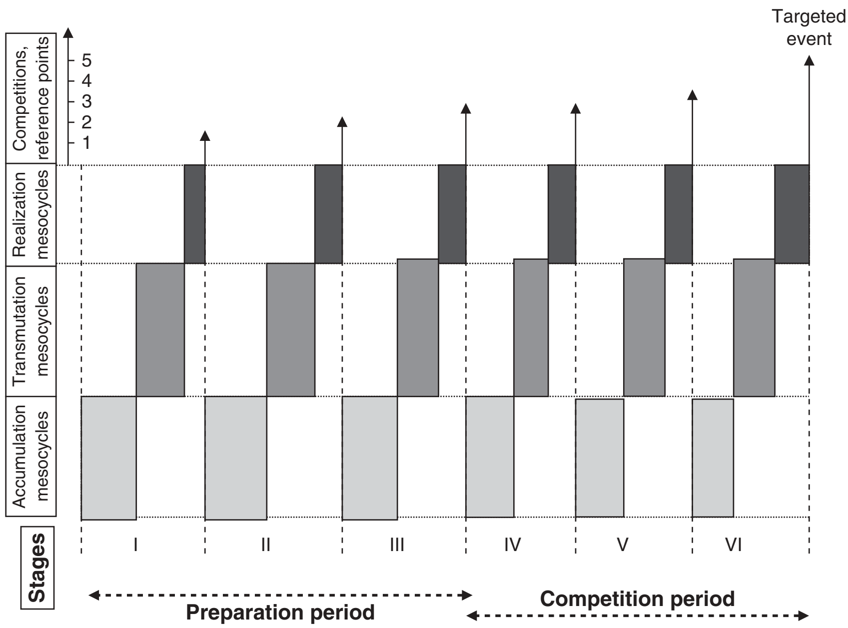

Fig. 5. Schematic chart of a block-periodized annual cycle. The importance of competitions is depicted in reference points ranging from 1 (the lowest level) to 5 (targeted competition).[94,95]

4. Conclusions

The challenge of this paper was to introduce training periodization by citing the early efforts of the pioneers and trying to present its most up-to-date versions by summarizing recently introduced concepts and evidence. An indispensable part of the theory of athletes' preparation, training periodization encompasses both academic elements (generalized biological concepts, physiological background, theory of training) and practically oriented subjects (alternative coaching concepts, implementation of training blocks, etc.), which are equally important. The long history of traditional training periodization indicates its staying power as one of the most conservative scholastic components of training theory. The five decades in which training periodization has been used have been enough to demonstrate the merits and weaknesses of the traditional model. Its benefits derive from a more reasonable structuring of long-term preparation, whereas its drawbacks emerge from the conflicting responses produced by multi-targeted mixed training (table II). The non-traditional model, called 'block periodization', proposes a revamped training system, where the sequencing of mesocycle blocks exploits the favourable interaction of cumulative and residual training effects.

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