PREFACE

As the mud kicked up from the moist earth clung within his cleats, the pulse of his breath setting the rate of his stride, the distance between him and the goal narrowed. Hugging the sideline he kept pace looking towards the center to find aid, he stepped back and released. The rotation of his body contorting his spine sent radiating pains pulsing throughout his limbs. Collapsing, cushioned only by the soft earth, he fell to his knees reeling in pain. The game, though far from over, was now finished for him. Making his way to the sideline, the physical pain dulled by the psychological wounds, he braved through the torment. Unfortunately, the events of this day will haunt the memories of a once fearless athlete for a lifetime…

Injury is an unfortunate risk that is still an unavoidable part of athletics today. Over the past decade, the scientific information on athletic injury in general, and integrative models of injury rehabilitation in particular, has increased considerably. As an example, a database search of peer-review articles from Medline, *SportDiscus* and *PsycInfo* between 1970 and 2006, using a variety of search items and combinations of terms (e.g., "return to sport," "psychology of athletic injury," "sport injury") returned more than 2,000 sport injury articles. Using the search engine *PubMed* (National Library of Medicine) for the term "*psychology of injury*" there were 1,990 articles available between the years 1994-2005, compared to 930 for the years 1966-1993. In recent years, a number of models, theories and hypotheses describing the physical, biological, behavioral, cognitive and affective aspects interactively influencing the healing process have been developed. The feasibility of these models, although in most cases contradictory, has been overall justified in a clinical setting. That said, despite dramatic advances in the physical education of coaches, the fields of medicine, athletic training and physical therapy, sport-related traumatic injuries is our major concern. It is a matter of fact that athletic injuries, both single and multiple, have a tendency to grow dramatically. Accordingly, the prediction, prevention, and, if possible, reduction of sport-related injuries are among the major challenges facing the sports medicine world, research and clinical community to-date.

The purpose of this book is to accumulate the latest developments in science of athletes' training from "injury-free" perspectives, along with psychological analyses, evaluation, and management of sport-related injuries, including traumatic brain injuries. It is this author's attempt to classify athletic injury with respect to its underlying causes and consequences. Clearly we are still far from a complete understanding of the major causes and multimodal consequences of sport-related injuries. The ***clinical significance*** of research into sport-related injures stems from the fact that the number and severity of injuries in athletes have a tendency to

grow exponentially, despite advances in coaching techniques, and technological advances in sports equipment and protective devices. For example, it have has been estimated that just in high school football alone, there are more than 250,000 incidents of mild traumatic brain injury each season, which translates into approximately 20% of all boys who participate in this sport. The incidence of injury for men's basketball games is 9.9 injuries per 1,000 athlete-exposures. The injury rate in gymnastics is about 15.19 injuries per 1,000 athlete-exposures. These are really "scary" statistics clearly indicating that modern sport is far from safe. Some details of injury epidemiology in athletics are depicted in this book.

Currently, there is no consensus among medical practitioners in terms of a generic definition and classification of injuries in athletics. The existing diversity in definitions of the term "sports injury" is apparent in the relevant literature and most likely accounts for disagreements in reported research findings and clinical practices when dealing with injured individuals. The classification of injuries, such as acute, chronic, etc., should be defined in conjunction with the severity of the injury (mild, moderate, major, sport disabling, catastrophic) to be recognized and fully accepted by coaches, athletes and medical professionals. Obviously, psychological risk factors, athletes' personalities, fear-related issues, adherence toward rehabilitation protocols and numerous other attributes of injury have never been considered within the scope of epidemiological research on the prevalence of certain injuries in certain sports. However, neither proper assessment nor appropriate treatment protocols could be developed unless multiple physical, biological, psychological and sociodemographic substrates are interactively considered when dealing with injured athletes.

It is also important to stress the ***conceptual significance*** of basic science and clinical research on various perspectives of injury. This issue has been addressed in a number of chapters of this book. For example, the effects of improper balance as a fundamental skill, progressive muscle fatigue, fear of injury and pain issues from both basic neuroscience and clinical research viewpoints will be discussed within the scope of this book. The need for an advanced conceptualization of injury in athletics stems from the fact that no two traumatic injuries are alike in terms of mechanism, symptoms, or symptoms resolution.

There is still confusion among coaches and medical personnel in terms the criteria for injured athletes' *readiness for sport participation* versus *readiness for competition*. It is important to note that: "*physical symptoms resolution of an injury is not an indication of injury resolution per se.*" Although, the reality of athletics is that return-to-sport participation criteria are defined by presence and/or absence of symptoms of injury. Specifically, physical symptoms resolution (i.e., no evidence of residual tissue damage, restored anatomical integrity of joint, etc.) and functional symptoms resolution (i.e., ROM, strength, stamina) are two major criteria of return-to-

play. Regarding traumatic brain injury, athletes are allowed to return to play when common symptoms of concussion (i.e., headache, fatigue, light or sound sensitivity, etc) are resolved. Is this really the cornerstone for clearance of the athlete for sport participation? In fact, residual dysfunctions and structural damage may still be present, but not observed due to numerous factors, including both extrinsic (i.e., lack of sensitivity of the assessment tools) and intrinsic (i.e., the athlete's desire to quickly return to sport participation because "… an injured athlete is worthless.")

Now, in terms of concussion in modern sport, that indeed should be treated as a "silent epidemic." The need for further understanding of concussion stems from the fact that, according to Dr. Robert Cantu, injury to the brain is the most common cause of death in athletes. It is conventional wisdom that athletes with uncomplicated and single mild traumatic brain injuries (mTBI) experience rapid resolution of symptoms within one to six weeks after the incident with minimal prolonged consequences. However, there is a growing body of knowledge indicating long-term disabilities that may persist up to ten years post injury. Recent brain imaging studies have clearly demonstrated the signs of cellular damage and diffuse axonal injury, not previously recognized by conventional imaging and neuropsychological examinations, in subjects suffering from concussion. It is a most striking fact that progressive neuronal loss in concussed subjects, as evidenced by abnormal brain metabolites, may persist up to thirty-five days post-injury. Note that current clinical practice is that athletes suffering from mild to moderate forms of TBI are usually cleared for sport participation within ten days post-injury. As a result, athletes who prematurely return to play based upon subjective symptoms resolution may be highly susceptible to future and often more severe brain injuries. In fact, concussed athletes often experience a second TBI or even multiple concussions within one year post initial brain injury. Moreover, every athlete with a history of a single mild TBI who returns to competition upon symptoms resolution still has a risk of developing a post-concussive syndrome with potentially fatal consequences.

Humans, in general, and athletes in particular, are able to compensate for mild or even severe physical and functional deficits because of redundancy in human neural, motor and cognitive systems. This in turn, allows for the reallocation of existing resources such that undamaged pathways and functions are used to perform cognitive and motor tasks. This functional reserve and overall capability to accomplish the testing protocols gives the appearance that an athlete has returned to pre-injury health status, while in actuality the injury is still present and hidden from the observer. As a result, premature return to sport participation based upon physical symptoms resolution may put athletes at high risk for recurrent injuries and the development of permanent psychological trauma. In fact, there is still no agreement upon a psychological diagnosis and definition of psychological trauma, and there is no known comprehensive treatment of psychological

trauma in athletes. It is a growing concern among medical practitioners and coaches that athletes with an initial injury are prone to suffering from recurrent and more severe injuries. It is feasible to suggest that one of the major factors of recurrent injuries in athletes is premature return to sport participation based upon questionable assessment of symptoms resolution.

OUTLINE OF THE BOOK

We will now provide a few more details on the organization of this book's content. There are **5** main parts, which provide analysis of the most recent basic science and clinical research on sport-related injuries. This book is focused on both applied and conceptual issues regarding the classification of injuries, common coaches' errors leading to injury, coaches' and athletes' viewpoints on injury, the development of psychological trauma in athletes, traumatic brain injuries and basic principles of rehabilitation.

Currently accepted in clinical practice and research classification of injury, prevalence of injuries in different sports, athletic injuries from coaches' and athletes' perspectives constitute **Part 1**. Several chapters will discuss basic principles of elite athletes' preparation and common coaches' errors including problems associated with:

- Confusing classifications of injury;
- Improper planning and training periodization;
- Whole body postural control and balance;
- Progressive muscle fatigue and overloading;
- Nutritional aspects

Coaches and athletes' viewpoints on injury, including psychological responses to injury, constitute **Part 2**. Numerous interviews with collegiate and professional coaches and athletes, and descriptions of psychological methods and diagnostic procedures well-accepted in clinical practice, case studies, current practices dealing with injured athletes and future challenges are the heart of this section. In addition, a discussion of overuse "abuse" injuries in athletics is included in this part of the book. It is important to note that one of the major coaching errors in modern sport is the lack of appreciation for the proper assessment of physical fitness. This issue will be also discussed within the scope of Part 2.

Current psychological research within the conceptual framework of "psychological trauma" in athletes constitutes **Part 3**, which includes a number of chapters summarizing experimental research on fear of injury and different forms of pain resulting from sport-related injuries. Special emphasis will be given to the aspect of the development of fear of re-injury and fear of movement due to anticipated pain, i.e., "*kinesiophobia*," as a predisposing factor for long-term psychological trauma in athletes. Behavioral indexes of fear/generalized anxiety and the development of

bracing behaviors as a result of injury will be discussed as well. Moreover, factors of age and gender as a predisposition for athletes' individuated responses to injury will be discussed in a special chapter of Part 3.

Part 4 of the book constitutes current information on traumatic brain injuries in athletes. Assessment scales and return-to-play guidelines that are well accepted and currently debated in clinical practice will be discussed within the scope of this section. Pediatric concussion, which is a major concern among medical practitioners today, will be also discussed within the scope of Part 4.

Finally, basic concepts and principles of integrated rehabilitation aimed at a timely return to sport participation will be discussed in **Part 5**. The special chapters of this section will be focused on the specialized treatment and rehabilitation of injured athletes, including the feasibility and applicability of virtual reality (VR), goal-setting and neurofeedback protocols in a clinical setting.

To my knowledge, multimodal perspectives of injury in athletics, including a discussion of the major causes and consequences of sport-related injuries with a special emphasis on coaches and athletes' viewpoints, have never been accumulated in a single source. Since the topic of sport-related injuries is included in most of the Kinesiology, Sports Psychology, Exercise and Sport Science, Athletic Training, Physical Therapy and Neuroscience curricula, it is anticipated that this book will be considered for adoption as a valuable asset and/or supplementary reading source within kinesiology, exercise and medical sciences programs.

Professor
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CHAPTER 2

SCIENCE OF TRAINING AND INJURY IN ATHLETICS

1. INTRODUCTION

Over the past 45 years or so, we have achieved significant scientific understanding of many physical factors involved in the development of various aspects of training, including specific strength and conditioning training. This has allowed more effective programs to be used for athletes' safety and preparation for competitions. Specifically, several components of training, such as skills, speed, strength, stamina and psychological skill training have been a focus of numerous text and research. The current conceptualization of science of training, basic principles of training theories as well as specific safe methods of strength and conditioning for athletes, have been summarized in *Science and Practice of Strength Training* (Zatsiorsky, 1995). The major theme of this book aims to provide scientific basis for the concept of *adaptation* as a *law of training*. Indeed, proper exercise, sport-specific drills and/or regular physical and psychological load is a very powerful stimulus for adaptation (i.e., organisms' adjustment in its environment). Accordingly, the major objective of athletes' preparation should be inducing specific *adaptations* in order to improve sport performance via: (a) carefully planned; (b) skillfully executed; and (c) goal-oriented training programs. From practical perspectives, at least four important features of the adaptation process should be considered by a coach in order to make training programs effective and most importantly safe for the athletes. Otherwise, athletes may experience and express various forms of *maladaptive* responses to training and associated performance saturation/deterioration with high risk for sport-related traumatic injuries. Athletes' adaptive responses are usually characterized by an increase in both physical properties, such as strength, speed, etc., and associated psychological indices, including emotional stability, proper level of motivation and vigor. According to Zatsiorsky (1995) there are four essential features of adaptation process as outlined below:

(1) **Overload.** The most challenging issue that coaches face daily is to provide an opportunity for maximal performance enhancement and secure a safe and injury free coaching environment. There is always a possibility of injury due to the nature of athletic activity that coaches should constantly be aware of. Due to coaches' primary responsibilities, which are an achievement of maximal performance and secure winning, positive (but not negative) training effect should be their major goal. However, positive

training effect may take place only if training load is above the habitual level. In other words, if training load in terms of the volume and intensity is the same over an extensive period of time, there will be no additional adaptation resulted in physical fitness saturation. If the training load and intensity are too low, detraining may occur, meaning that an athlete may not improve his/her physical status despite continuous training. On the other hand, if the training load and intensity are too high, an athlete may experience *maladaptive* responses to training and an increase in risk of injury. Athletes' individual responses (both adaptive and maladaptive) should be carefully monitored by the coaches in order to achieve progressive improvement and most importantly, to prevent overload-related injuries. Specific signs and symptoms of athletes' overtraining will be discussed elsewhere in this book. Overall, training load can be roughly classified according to three important principles:

(a) *progressive stimulating*: when the training volume and intensity are above individually defined neutral zone allowing for adaptation to occur;

(b) *retaining*: when the magnitude of the load remains the same in the individually defined neutral zone, so the level of fitness may maintain for a long time;

(c) *detraining*: when the magnitude of the load tends to decrease and associated performance deterioration and/or functional capacities of the athlete may be observed.

It should be noted however, that the aforementioned principles should be considered with regards to hierarchy and duration of the periodical training units (i.e., general preparation period, competitive preparation period and transition period). In addition, it is important to note that these principles are also athletic fitness/skill level dependent. The aspect of individualization in terms of novice versus elite athletes' responses to training load will be discussed in more details in the following text.

(2) **Accommodation.** Positive training effect and associated positive psychological responses to the training load may take place if accommodation is prevented via proper training programs. In essence, accommodation refers to the training program when the same training program and type of exercise remains constant over a prolong period of time. For example, a diver that just performed optional dives (regardless of degree of difficulty) and ignores fundamental dry land, gym and conditioning training, a decrease in performance level will ultimately be observed. This is kind of a manifestation of biological law of accommodation. According to this law, an organisms' response to a given constant stimulus saturate or even decrease over time. Not surprisingly, experienced coaches always vary their exercise programs by (a) constantly replacing exercise routine; (b) switching from aerobic to anaerobic types of activity; and (c) balancing specificity and generalization of training sessions. It is also advisable for coaches to schedule flexibility and relaxation exercises between heavy resistance

strength drills to speed up recovery, prevent loss of flexibility and overall to avoid accommodation. According to Zatsiorsky (1995), training programs should satisfy at least two demands to avoid accommodation and to preserve specificity via: (a) quantitative modification (changing training loads in terms of the volume and intensity of exercise); and qualitative modification (replacing the exercises aimed at developing the athletes' specific functions such as strength, coordination/flexibility, and endurance).

(3) **Specificity.** Training adaptation is highly specific in nature. Success and injury free in particular sports require that the athletes posses specific qualities. What would be essential for a long distant runner could de detrimental or even harmful for a long jumper. Well developed upper body for a gymnast may not be beneficial for a springboard diver. Even among divers, depending on the event (springboard versus platform diver) current practices tend to provide differential training in order to develop sport diving specific qualities. As an illustration, excessive muscular development of the lower body compared to the upper body in springboard divers is an obvious necessity that needs to be achieved via specific strength training (see also Figure 1 below).

Figure 1. World Best Divers body compositions most likely influenced/selected for the platform (left, both female and male) and springboard (right, both male and female) events.

Current trend in diving is to achieve excessive body mass and explosive power of the lower body allowing the improvement of the jumping skill and height of the dives. As can be seen from this picture, top world springboard divers (right Pictures) are "more developed" and have larger leg muscles compared to the platform divers (left Pictures). Both males and females are most likely to encounter differential and special training programs, even

within the same sport of diving. [Pictures were taken during FINA 2007 Diving World Series, Nan Jing, China, with permission from divers].

Another way to consider specificity of training program is to select sport-demand-specific routines. Clearly, fish can swim because they swim, birds can fly because they fly, frogs can jump because they jump, divers can dive because they dive, and so on. Thus, strength, flexibility and endurance training are highly specific in various sports. Unfortunately, this important principle of specificity of training programs is often ignored by the coaches. For example, it is a common practice in collegiate athletics that divers and swimmers utilize similar heavy resistance workouts for upper body, particularly during preparation period. This is inconsistent, at least, with the principle of specificity. Coaches should be aware that "what is honey for a swimmer could be poison for a diver".

Similarly, in the field of athletic training dealing with injured athletes, at an early stage following acute injury, it is important to control inflammation and regain the pre-injury range of motion. Accordingly, a specific exercise rehabilitation program should be utilized for this purpose to reduce probability of slow recovery and/or risk for re-injury. At the later stage of acute injury recovery, the muscle strength should be a major target for rehabilitation, thus, specific strength training drills must be utilized at this stage of recovery. Finally, preparation for the execution of specific drills should be a focus of rehabilitation. Accordingly, more sport-specific rather than general conditioning, strength and flexibility exercise should be incorporated into rehabilitation sessions.

Another aspect of *specificity* may be considered from perspectives of *identical-elements theory* (see also theories of transfer initially developed by Thorndike back in 1914 and further elaborated within the scope of current motor control and learning research). In essence, in order to achieve positive transfer of learning between various skills and exercise routines, the main elements underlying different skills or situations surrounding performance must be identical and similar in nature. In other words, a major assumption of this theory is that positive transfer between skills is not based upon any general and unrelated performance, but rather very specific in nature. Similarities between stimuli (type of exercise) and responses (developed skills) are complementary in nature. The use of dry-land and gymnastic training aimed at practicing complex exercise maneuvers complement (positively transfer) to the springboard diving. Conversely, as the degree of similarity between stimuli and responses are declined, conflicting consequences may be experienced. For example, because of the dissimilarity between diving and gymnastic somersaulting techniques, athletes' transition from gymnastic to diving may not likely foster any positive transfer. Similarly, because of the dissimilarity between the two sports, tackle techniques in football may not be applicable (but rather difficult to transfer) for rugby. In fact, a vast majority of concussive injury in rugby is due to

tackle techniques that the rugby players adopted from their past experience playing football. Coaches, who understand basic principles of specificity, may avoid numerous problems and most importantly, may provide an optimal injury free training environment for their athletes.

(4) **Individualization.** Due to genetically predisposed and environmentally influenced individual differences among people, the same exercise routines and training program may elicit differential effect among athletes. Indeed, people are different in terms of anthropometric dimensions (larger/smaller; stronger/weaker; more or less flexible; more or less fatigable; emotionally stable/unstable; risk taker/risk avoider; etc.). Therefore, any attempts to mimic performance style and or techniques of world best athletes have proven to be useless or even harmful. For example, numerous attempts to "copy" Greg Louganis' diving style by novice divers led to significant deterioration of their own styles and overall performance. Similarly, mimicking the best Chinese divers' clean entry and/or fast somersaulting techniques (which was a tendency a few years ago among USA diving coaches), has proven to be devastating. However, the acquisition of fundamental skills and coordination patterns should be essential regardless of aforementioned individual differences among athletes. Fundamentally correct posture and basic skills should be trained regardless of sports, whether it be complex coordination, games and/or cyclic in nature. Not surprisingly, apparatus gymnastics is called the "mother of all sports" and required as an essential training method for youngsters. With coaches' creativity based on solid fundamental skills and qualities, injury controlled training methods proved to be successful. No average methods exist for exceptional athletes. "*Only average athletes, those who are far from excellent, prepare with average methods. A champion is not average, but exceptional*" (Zatsiorsky, 1995).

2. TRAINING PERIODIZATION

One of the common errors leading to athletic injury is improper planning of both athletes training sessions and competitive activities. In essence, "…Failure to plan is planning to fail" (Balui, 1995). Poor planning and inadequate duration of preparatory season and lack of general conditioning prior to competitive season are the major causes of injury in athletics. Both lack of proper planning aimed to reach peak performance at proper time and lack of flexibility in planning aimed at correcting training programs, if necessary, may have severe consequences not only from performance enhancement but also from injury prevention perspectives. For example, adding another challenging competition in prior planned competitive calendar forces athletes and coaches to reconsider not only preparation for

this specific event, but also modify the whole competitive season. Premature transition from general preparatory to specific preparatory phases is another coaching error leading to injury early in the season. The most common challenges facing coaches and other sport practitioners may be summarized as: (a) how to design a rational plan for a sufficiently long as well as for short-time training period; (b) how to skillfully execute a well-designed plan in an optimal manner in order to satisfy the general law of training (e.g., adaptation), reduce the risk of overtraining and potential injuries; and (c) how to reach the optimal peak of athletes best abilities precisely at the time of major events/competitions of the season, not before/and or after. The whole concept of training *periodization* is to address these challenges. It should be noted that there is still a lack of clarity, complete with controversy, in terms of how to define the concept of periodization, and most importantly, how to properly plan a training load.

Generally speaking, *periodization* is "…a sensible and well planned approach to training, which maximizes training gain and performance enhancement." (Dawson, 1996). Training *periodization* can also be defined as "…the purposeful sequencing of different training units (long-, medium- and short-term training cycles and sessions) for the attainment of the athlete's desired state and planned results" (Issurin, 2003). This definition is similar to Nadori and Granek (1989) suggesting that "…periodization is the predetermined sequence of training sessions and competitions.**"**

The following text contains a summary of the most general current notions and ideas regarding the training *periodization* with respect to the *classic approach* (Matveev et al., 1977). This issue is presented based on materials and documents kindly offered by Dr. Issurin (with permission from the author). It should be noted that a "classic approach" has been predominant for decades, particularly with regard to the *block composition* design.

2.1. Training Periodization: Looking Back and Current Trends

Training *periodization* as a sport scientific concept and theory of athletes' preparation was elaborated during the 1950s-1970s in the former USSR by Russian scientists Matveyev (1977), Ozolin (1970) and many other prominent leaders in the field at that time. This theory was adopted and propagated in Eastern Europe and more recently in Western countries (see Bompa, 1984; 1999; Dick, 1980) and has developed as a core foundation of planning in high-performance Olympic sports. In general, the training *periodizaion* theory exploits the periodical changes of all biological systems and social activities typical to human beings. Specific to sport reality, at

least four rationales should be considered as the factors that determine the periodical changes in the context of athletes' training:

a) **Repetitive patterns of nature:** Exogenous (external) and endogenous (internal, or circadian) rhythms are one of the fundamentals of biological systems, including humans. The seasonal changes as well as the daily changes experienced by living systems predetermine all biological activities both in terms of volume and intensity. The months and weeks naturally divide social and economic life into historically and traditionally consolidated cycles, which are incorporated into general adaptation: the weekly resting rhythm. Clearly, all biological, social, industrial and other activities are subordinate to exogenous rhythms of nature; it would be strange if sport and athletic activities were an exception to these patterns of nature.

b) **Adaptation as a general law:** As mentioned in the previous text of this chapter, the law of adaptation dictates and determines the athletes' training and preparation for competitions. To reiterate, athletes should avoid excessive accommodation to habitual loads in order to improve desired qualities (i.e., general conditioning, specific strength, flexibility and stamina). Accustomed (habituated) stimuli, such as a constant training load and intensity, cannot continue to be effective. In order to regenerate the adaptability of the athletes, their training program and exercise repertory must be periodically changed and renewed according to demands and individual goals of an athlete. In other words, an excessively stabilized and fixed training program leads the athlete to an adaptation barrier, where he/she is forced to dramatically increase the magnitude of habitual workloads in order to increase the positive body response. From this point of view, periodic changes of the training program should be considered, and carefully planned within the scope of *adaptation law*.

c) **The sequencing of different training aims:** Training in any sport is characterized by complexity, diversity, and variety. General and sport specific motor abilities, both technical and tactical skills/drills, cannot be developed simultaneously and maintained throughout the entire season. A more specific technical skill, for example, should be based on the appropriate level of motor fitness functional and psychological readiness of the athletes. In fact, a great number of injuries that an athlete suffers are from improper techniques and movement forms, which may be a result of improper physical fitness, or forcing the athletes to sacrifice movement fundamentals for the sake of performing the required drills. Fundamental skills and techniques (i.e., proper balance/posture and movement basic forms) must be acquired prior to acquisition of more specific skills. Similarly, excessive range of motion and joint stability/flexibility must precede the learning of advanced skills. Repetitive sequence of various training properties, individually defined and goal-oriented in nature, should be designed within both short and long-term training programs.

d) **Competition schedule:** A vast number of injuries in athletics occur due to *multiple peak performance* problems. The number of "most important events" dramatically increased over the past decade pushing the athletes to force their readiness for each event, skip fundamental training and ignore under-recovery symptoms. Having said that, overall there is established events (competitions) that take place periodically both nationally and internationally. Specifically, various bodies such as the International Olympic Committee and a number of international, national, and domestic sport associations control the frequency and timing of competitions. Thus, the competition calendar established by these bodies determines and dictates preparation, competition and recuperation cycles of athletes' training programs. The quadrennial cycle of Olympic preparation provides an excellent example of periodic changes which affect and dictate the activities of top world athletes. Traditional specification of periodic cycles of training/competition/recuperation phases in world class athletes' preparation is presented in Table 1 below.

Table 1. An Example of Hierarchy and Duration of the Periodical Training Units in Olympic Athletes

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

Training cycles of medium duration, called mesocycles, were traditionally proposed by classic theory, although there are several authors who do not consider these training units in their research (see, e.g., Bompa, 1999; Letzelter, 1978). The modes, specific aims, and content of mesocycles have been considered by many sport researchers who have suggested up to ten types and sub-types with more or less convincing argument (e.g., Harre, 1982; Matveyev, 1977; Platonov, 1997). The microcyles, as the small training cycles, are the most comprehensive, commonly accepted and least disputable terms, and are mostly defined as weekly cycles.

It should be noted that there is a current tendency to reconsider the major assumption of the training periodization outline in Table 1, due to various practical reasons, such as:

- increased number and level of competition throughout the entire season;
- increased complexity of routines, especially in complex coordination sports;
- earlier maturation of athletes, requiring to consider developmental aspect of athletes preparation;
- increased total volume and intensity of training load the whole year around;
- current practices and attempts to simultaneously develop motor abilities and functions such as strength, flexibility and stamina;
- increased number of alternative views on the nature of training periodization;
- progress in training methods and sport technologies, and protective devices, such as helmets, mouth guards, pads, braces, etc.;
- increase in the financial and other extrinsic sources for motivation to compete constantly at their peak level.

Periodical training units afford a great deal of freedom for creativity for coaches and athletes. However, the competitions calendar in most cases dictates the selection of the appropriate sequences, content, and duration of the training cycles. Specifically, the competition calendar dictates different modes of planning in order to reach the peak performance at the right time of the most important event of the season. Thus, this is the direct responsibility of coaches to design the plan of the training program focusing on principal features such as timing, peaking and training load distribution.

The general conceptual framework for *periodization* of training programs, including preparatory, competitive and transition periods, was initially proposed by Matveev (1977) and Harre (1982) and more recently modified by Issurin (1985-2004). It is important to note that within the preparatory period, there is: (a) an initial stage aimed at developing and enhancing the general motor abilities and functions, and (b) a later stage aimed at developing and enhancing more specific motor abilities and functions. Similarly, within the competitive period, there is also: (a) a general preparatory stage and (b) an acute and most immediate pre-competition stage characterized by different aims and should be achieved by various properties/features of training loads. Finally, the most common coaching error associated with training load and planning is the underestimation of the transition period aimed at the restoring of physical, psychological and functional resources. Some additional details for coaches to fully appreciate the modern approach to *periodization* of training program can be found in Table 2 below.

Table 2. Goal-Oriented Stages of Training Periodization

Period	Stage	Aims	Workloads' features
Preparatory	General preparatory	Enhancing the level of general motor abilities. Enlarging the potential for various motor skills	Relatively large volume and reduced intensity of main exercises; high variety of training tools
	Special preparatory	Development of the special training level; enhancement of more specialized motor and technical abilities	The loads' volume reaches their maximum; the intensity increases selectively
Competitive	Competitive preparation	Enhancing event-specific motor fitness, technical and tactical skills; formation of the model of competitive performance	Stabilization and reduction of the volume; increase of intensity in event-specific drills
	Immediate pre-competitive training	Accomplishing event-specific fitness and reaching readiness for main competition	Low volume, high intensity; the fullest modeling of forthcoming competition
Transitory	Transitory	Recovery and recuperation of physical, functional, and psychological spheres properties	Active rest; use of pleasant, attractive, and variable activities

3. TRAINING EFFECTS

A Coaches' knowledge about differential training effect is fundamental in terms of proper planning of workout load, selection of exercise, its duration and intensity, timing of administration and timing of recuperation. Currently well-accepted in sport science community taxonomy of training effects (Zatsiorsky, 1995) includes:

(a) ***acute effect***, referred to changes induced by a single bout of exercise;

(b) ***immediate effect***, referred to changes induced by one workout session or training day;

(c) ***cumulative effect***, the result of a series of workouts overall certain time frame;

(d) ***delayed effect***, referred to changes that occur over a given time interval after a certain goal oriented specific program;

(e) ***residual effect***, which operates with the retention of changes induced by systematic workloads after the cessation of training beyond a certain time period.

The *residual* training effect is well-observed but the least studied phenomenon of the athletes' response to the training load. In 1991 Counsilman & Counsilman (1991) introduced and conceptualized residual training effect, however, this effect still is not well-accepted and understood among sport practitioners today. The following paragraph contains a few details regarding this effect with respect to "injury-free" planning of training programs as discussed.

Overall, the phenomenology of the *residual* training effect is closely related with the process of *detraining*, which in the past was defined as saturation of progress or "loss trained functions" when training is stopped and/or interrupted for some reason. In fact, *detraining* in elite athletes from different sports may occur selectively and "targeted" toward only certain abilities (i.e., loss of strength) when it does not receive sufficient strength input. For example, it is well-documented that in elite and highly trained endurance athletes the maximum oxygen uptake decreases when the total weekly volume is reduced below a certain level (Steinacker, 1993; Steinacker et al., 1998). Interestingly, Wilmore & Costill (1993) reported a considerable decrease of swimming-specific strength after four weeks off practice. It was suggested that the risk of *detraining*, in general, and loss of aerobic endurance may occur despite the large volume of highly intensive exercises (Mijika, 1999). To reduce potential *detraining*, the consecutive rather than simultaneous development of sport-specific abilities approach should be utilized in elite athletes (Bondarchuk, 1981; Issurin & Kaverin, 1985). Proper prediction of duration and amount of *residual* effect of previous training should be taken into account in order to define the rational sequencing and timing of different training cycles. From this perspective, it is extremely important to know which factors and in what manner may influence the duration of *training* residuals. Some details in terms of duration and underlying physiological mechanisms associated with residual effect of sport-specific abilities are summarized in Table 3. It should be noted, however, that more search is still needed to justify the advantages of consecutive approach for development of sport-specific abilities.

Table 3. The Duration and Underlying Physiological Mechanisms of the Residual Training Effect for Different Physical (Motor) Abilities (Issurin & Lustig, 2004)

Physical (motor) ability	Residual's 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 the muscle fibers' 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 neuromuscular interactions and motor control, increased phosphocreatine storage

The coaches' knowledge about training *residuals* and temporal *detraining* is extremely important for planning transition at some stage of athletes' preparation from simultaneous to consecutive development of the sport-specific fitness components and abilities. The overall rule of thumb is that coaches should remember the necessity of transition from simultaneous to successive/consecutive development of the training program allowing the enhancement of the *residual* effect of exercise and prevent detraining. By doing so, the principle of variability of training programs can be implemented and aimed at achieving injury-free peak performance at proper time with no indication of over-training. The lack of appreciation of training effects may have serious consequences for elite athletes' well-being.

On a final note, the general principle of differential effects of training may also be applicable for rehabilitation programs of injured athletes. It is well-accepted in the clinical practice that several important steps should be utilized during sport injuries rehabilitation programs for athletes suffering from various orthopedic injuries. Specifically, control of inflammation after knee injury should precede specific exercise aimed at increasing range of motion (flexion first and then extension). The next consecutive step should

be specialized strength training followed by endurance and implementation of sport specific drills to restore pre-injury functional capacities. A simultaneous approach aimed at recovering multiple functions may be detrimental for athletes' recovery protocol, prolong reacquisition of sport specific functions and, most importantly, may put athletes at high risk for recurrent injuries. Within the conceptual framework of rehabilitation *residuals*, comprehensive research is needed to examine the type of exercise, its duration and physiological mechanisms underlying maximal positive effects for various sport-related injuries. "*How much is not enough and how much is too much*" in terms of the volume, intensity and duration of breaks between rehabilitation sessions should be a primary concern of medical professionals to fully rehabilitate injured athletes. It should be noted that this important principle of training/rehabilitation residuals has not been seriously considered and appreciated in the clinical setting.

4. BLOCK COMPOSITION CONCEPT: OVERVIEW

There are many contradictions and controversies in current practice and sport science regarding the issue of *periodization,* in general, and specifically in differential training effects. In attempts to resolve these existing contradictions and to achieve at least some consent among sports science experts and coaches in charge of elite athletes preparation, the revised approach to training *periodization* has been recently proposed (Issurin, 2004). This approach, so-called the *Block Composition Concept* (BCC), summarizes the general principles of elite athletes preparation and provides guidelines for alternative training *periodization*, with specific focus on short-term planning.

Specific focus of the training workloads is the most important fundamental principle of the BCC. Indeed, empirical evidence and anecdotal facts suggest that only highly-focused training workloads can produce sufficient stimulation for the development of required functional properties and the acquisition of skills/motor abilities in elite athletes. The concept of block-mesocycles implies that at least three differential effects of training load should be considered and carefully controlled by the coaching staff. The first one is *accumulation*, where acquisition of basic fundamental motor skills and abilities should be a main focus of the training session. Specifically, basic jumping skills, proper body alignment and posture, and hand-torso-leg coordination should be acquired and consolidated first before transition for acquisition of more complex skills such as forward and backward somersaults in gymnastics. The lack of aforementioned basic skills and premature transition to more advanced motor modalities may put athletes at higher risk for injury due to improper techniques.

The second effect is *transmutation*, characterized by creating a training environment which affords maximal positive transfer and utilization of previously acquired fundamental skills to sport-specific drills. For example, proper arm swing techniques synchronized with proper upright posture during the initiation of vertical jumps should benefit skillful execution of back single and double somersaults in gymnastic and springboard diving. Another example from the sport of gymnastics is that the proper head position during a vertical jump may significantly help to prevent disorientation and potential serious injuries during multiple somersaults, which is a well-known phenomenon. As discussed in the previous text, the *identical-elements theory* (Thorndike, 1914) and principal of similarities between stimuli (type of exercise) and responses (developed skills) may maximally foster positive transfer of basic to more specific skills. Also, the dissimilarity between acquired basic and sport-specific skills may induce numerous improper movement forms and techniques which are detrimental for athletes' growth and development.

Finally, *realization* effect of the training load assumes that an athlete should utilize his/her acquired fundamental and sport-specific potentials and skills and reach the optimal plan results at the peak of performance targeted on the most important event of the season. Again, this is the so-called "medium-size training cycles" or "block-mesocycles" characterized by the successively/consecutively focused development of fundamental (earlier in the cycle) and more sport specific (later in the cycle) abilities/skills. The training effects with respect to residuals can be illustrated in the following manner (See Figure 2 below).

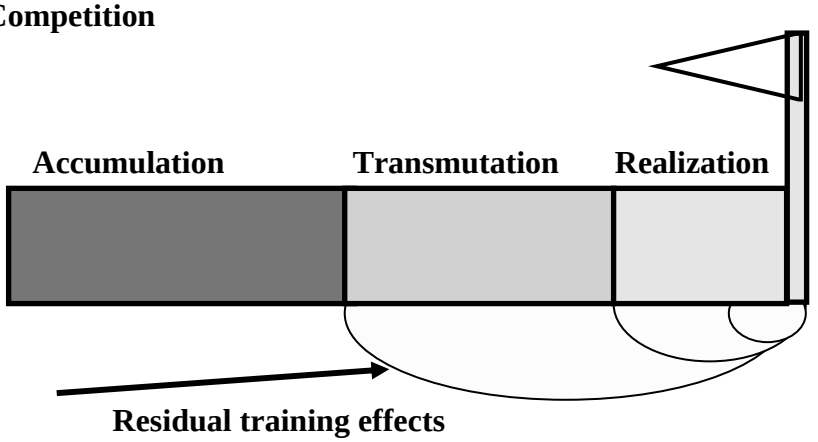

Figure 2. Superposition of the residual training effects induced by the sequenced blocks-mesocycles (adapted from Issurin & Shkliar, 2002 with permission the primary author)

4.1. The Annual Cycle Compilation

Similar to the classic approach, the annual cycle planning starts with the selection of major target-competitions of the season usually determined by international and national sport authorities. The specific item of the revised training approach is the subdivision of the entire annual cycle into a number of training stages. Each stage should contain a consecutive combination of extensive work on fundamental skills/abilities at the beginning of the season and more intensive work on sport-specific abilities with reduced volume as competitive stage approaches. Types of workout within the BCC aimed at achieving the accumulation, transmutation, and realization effects are shown in Table 4.

Table 4. The Main Characteristics of the Three Types of Blocks Meso-cycles

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 strategy
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
The tests' battery	Monitoring of the level of basic abilities	Monitoring of the level of sport-specific abilities	Monitoring of maximal speed, event-specific strategy, etc.

The rational sequencing of the meso-cycles within the training stage allows the optimal superposition of the residual training effects to be obtained, if properly planned. Figure 1 above shows the principal possibility of obtaining optimal interaction of the training residuals allowing high level of competitive performance of previously acquired both fundamental motor and specific technical abilities. It should be noted from Table 4 that training

residuals of fundamental skills and abilities last much longer then residuals of more specific abilities, while the residuals of maximal speed and event-specific readiness are the shortest ones (Table 4). Following this knowledge, the duration of the training stage is determined by the length of the training residuals and should be close to two months. In fact, the training stages can be shorter (near to peak season, for instance), or longer (at the season's beginning or due to specific needs).

Proper control of athletes' responses to the training load is an essential attribute of the science of training, allowing the prediction/prevention of athletic injuries. Accordingly, it is strongly recommended that the test battery should be reproduced in each stage of athletes' preparation for competition. In conjunction with actual results of competition, proper testing of athletes' physical, functional and psychological parameters may provide important monitoring and feedback information that can be used for future training corrections. As suggested, the number of training stages in an annual cycle is a sport-specific decision and depends on the number of external (i.e., number and location of major competitions) and internal (i.e., psychological status, predisposition for injuries, age and gender) factors.

Clearly, the *high volume and intensity of the training load required by modern sports is one of the major causes of injury in elite athletes*. Thus, proper realization of BCC may provide a number of benefits, including the fact that the Block Composition model allows the total mileage and time expenses for training to be reduced, without substantially changing the total number of workouts. The other benefits of BCC include:

- monitoring the detraining effect and focusing on a reduced number of abilities/skills successively acquired at each stage;
- providing appropriate tests, the so-called "dose-response-effect" analysis to control for maladaptive physical/physiological responses;
- providing psychological climate allowing a focus on the reduced number of targets; consequently the mental concentration and motivation level can be maintained more effectively throughout the entire season;
- controlling nutritional aspects requiring a high protein diet in order to enhance the anabolic effect of strength training; carbohydrate nutrients are particularly important in meso-cycles for special and strength endurance (Wilmore & Costill, 1993).

4.2. Bases of the Short-term Planning

The general propositions of BCC make more sense when considering short-term planning and properly designing the training micro-cycles and several workouts. At least two basic prepositions of the BCC immediately affect both the process and outcome of the short-term planning, namely:

- specific focus and concentration of the training loads on the minimum abilities-targets;
- consecutive step-by-step development and maintenance of abilities-specific targets.

That said, there are three major aspects of the short-term planning that should be considered by coaches when planning individual workouts to control for fatigue and maintain athletes' high level of motivation, including: (a) load-related *differentiation* of workouts; (b) *compatibility* of different training loads in several and adjacent workouts; and (c) basics of the training micro-cycle *compilation*.

Load-related differentiation emphasizes the importance of both physiological adaptation and mental concentration. For practical purposes, it is necessary to point out three general functions of workouts: *development, retention, and restoration*. The appropriate load level should be selected corresponding to these aims.

Compatibility of the specific training modalities within the single workout and within the workout series emphasizes possibility of both negative (interferences) and positive interaction of several immediate training effects. The BCC allows the prevention or at least reduction of negative interactions by the use of a compatible combination of exercise routines within certain training modalities (i.e., strength, flexibility, endurance).

Basics of the training micro-cycle compilation contain a number of specific statements including (a) no more than three training modalities (usually one dominant, the second – compatible with the main purpose, the third – modalities of restoration exercises) should be implemented simultaneously; it is postulated that 65-70% of the entire training time within one training session should be allocated to one or two purposed training modalities; (b) high intensity of workout depends on the context and outcome of the previous session focused on key targets. For example, the session with primary focus on strength training should be followed by a high intensity session focused on flexibility training and significant reduction of workout targeting the strength training; (c) minimizing the number of training modalities is particularly important and typical for elite athletes. The daily program for less experienced and particularly for junior athletes may be more diversified in order to maintain a high level of motivation and attractiveness.

CONCLUSION

There is always a trade-off between high-achievement and probability of overtraining as well as high risk of injury among elite athletes. Proper planning, specificity and individualization of the training program are key factors to consider. There are tendencies in modern sports to (a) standardize the training program within certain sports; and (b) modify the exercise content to achieve maximal adaptation and reduce the probability of accommodation.

The first tendency proposes the use of more or less standardized workload combinations within meso- and micro-cycle programs. The positive aspect of this tendency is the possibility of comparing the results and responses obtained in different training cycles with the same (or similar) workload combinations. This provides prerequisites for a current training control and improvement of sport specific training technology. The negative aspect is that the possibility of excessive accommodation when the athletes' response to a continuing stimulus decreases followed by a decrease in the training effect as well. This may force the coaches to reconsider the initial training routine with emphasis on an increased training load and ultimately putting athletes at high risk for overtraining and injury.

The second tendency relates to the effect of novelty when the unaccustomed exercises induce more pronounced adaptive responses. However, there is still a problem as to how to increase the effect of stimulus novelty when an athlete is accustomed to repetitive sport-specific exercises. Indeed, additional research, enhanced coaches' experience and quality observations are necessary to overcome existing controversies in training programs aimed at maximizing performance enhancement without jeopardizing the safety and well-being of athletes.

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