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INVITED BRIEF REVIEW

An Integrated, Multifactorial Approach to Periodization for Optimal Performance in Individual and Team Sports

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Sports periodization has traditionally focused on the exercise aspect of athletic preparation, while neglecting the integration of other elements that can impact an athlete's readiness for peak competition performances. Integrated periodization allows the coordinated inclusion of multiple training components best suited for a given training phase into an athlete's program. The aim of this article is to review the available evidence underpinning integrated periodization, focusing on exercise training, recovery, nutrition, psychological skills, and skill acquisition as key factors by which athletic preparation can be periodized. The periodization of heat and altitude adaptation, body composition, and physical therapy is also considered. Despite recent criticism, various methods of exercise training periodization can contribute to performance enhancement in a variety of elite individual and team sports, such as soccer. In the latter, both physical and strategic periodization are useful tools for managing the heavy travel schedule, fatigue, and injuries that occur throughout a competitive season. Recovery interventions should be periodized (ie, withheld or emphasized) to influence acute and chronic training adaptation and performance. Nutrient intake and timing in relation to exercise and as part of the periodization of an athlete's training and competition calendar can also promote physiological adaptations and performance capacity. Psychological skills are a central component of athletic performance, and their periodization should cater to each athlete's individual needs and the needs of the team. Skill acquisition can also be integrated into an athlete's periodized training program to make a significant contribution to competition performance.

***Keywords**:* training, coaching, nutrition, psychology, recovery, skill

Since ancient times, athletes have been guided by trainers and coaches in their quest for improved physical performance. By and large, the principles behind exercise training have been based on the intuition of more or less successful coaches, as well as tradition and folklore. However, at the turn of the 20th century, as physiologists started applying their skills to understand the biological mechanisms underpinning exercise and training adaptations, coaches and athletes began to recognize the importance of a more scientific approach to the training process. This approach initiated the application of principles and methods such as dose and response, interval training, circuit training, and the periodization of training.[1] However, periodization—simply understood as the systematic planning of long- and short-term training programs—has traditionally focused on the exercise aspect of athletic preparation, while neglecting the integration of other elements (such as nutrition, biomechanics, or psychology) that can impact an athlete's readiness for peak performance in competition.[1,2]

Although the concept of integrated periodization is not new, a systematic and scientific approach to this idea is lacking. Bompa[2] indicated that integrated periodization combines all the training components into a whole and matches them according to the periodization of the biomotor abilities, which dictates the diet and the psychological skills best suited for a given training phase. Unfortunately, the concept has not been developed any further to benefit from the continual evolution of scientific knowledge. Recent advances in various areas of the sports sciences can contribute to the development of integrated periodization, and thus make a significant impact on training theory and practice. The aim of this article, therefore, is to review the available evidence underpinning integrated periodization. In particular, this review will focus on the following aspects by which athletic preparation can be periodized for optimal performance in competition:

- Training periodization
- Periodization of recovery
- Dietary periodization
- Periodization of psychological skills
- Skill periodization

Training Periodization

One of the biggest challenges for coaches and athletes of all calibers is to design their long- and short-term training programs to induce optimal training adaptations and maximize performance at the desired moments of the competitive season. Long-term career paths are most often planned for athletes to peak at the end of a quadrennial period culminating with the Olympic Games, coinciding with their athletic maturity. In the short term, peak performance is usually attained by skillfully intertwining lengthy phases of hard, intensive training and shorter phases of reduced training.

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Team sport athletes, however, are usually required to perform consistently over several months for league format competitions, but also to peak for major regional, national, and/or international tournaments.

Phases of intensive training result in acute physiological effects that might limit performance capacity in the short term (days to weeks), but they also generate adaptive responses that eventually lead to improvements in sports performance. The intention of these intensive periods of training overload is to maximize medium- to long-term physiological adaptations to training, while ignoring the potential acute negative impacts. By contrast, reduced training or taper periods are introduced to diminish the detrimental impact of training while the physiological adaptations achieved during intensive training are further enhanced. Under ideal circumstances, this process will translate into maximal physiological adjustments and an optimal performance potential.[3] In less ideal circumstances, however, training programs may result in unwanted situations, such as underperformance, excessive fatigue, overtraining, illness, or injury forcing an athlete to interrupt his or her participation, with subsequent detraining effects.[4] In this context, periodization is a planning tool available to coaches, athletes, and sports scientists to organize their training and competition programs.[5]

Defining Periodization

Multiple definitions of the term "periodization" can be found throughout the sports performance literature. For instance, Lambert et al[6] defined periodization as the process of systematically planning a short- and long-term training program by varying training loads and incorporating adequate rest and recovery. Issurin[7] described the term as the purposeful sequencing of different training units (long-duration, medium-duration, and short-term training cycles and sessions) so that athletes can attain the desired state and planned results. Beyond the more or less subtle differences among definitions, periodization should probably be considered a flexible concept or method, rather than a rigid model, and a systematic attempt to gain control of the adaptive response to training in preparation for competition.[8] Norris and Smith[5] consider periodization, essentially, a systematic and methodical planning tool that serves as a directional template for a specific athlete. Rather than a rigid concept, periodization could be seen as a framework within and around which a specific program can be formulated for a specific situation. In this respect, the essence of a periodized training program design is to skillfully combine different training methods to yield better results than can be achieved through exclusive or disproportionate use of a single method.[9] A practical example of such a mixed-method approach can be found in Mujika et al,[10] who organized the training season of a world-champion paratriathlete with a flexible application of 2 consecutive periodization methods, depending on the primary target of each training phase, namely, achieving physiological adaptations or competition performance. In line with this contention, a recent systematic review on the effects of periodization and training intensity distributions on middle- and long-distance running performance suggested that different training approaches may prove valuable at different phases of the season and in preparation for competitions of varying distances. For instance, training early in the season could be organized to target specific physiological values (eg, heart rate, blood lactate concentration), but as the competition approaches, the focus would shift toward training at and around the race pace, irrespective of physiological values.[11]

Periodization Methods

According to Issurin,[7] Matveyev was the first author to summarize and compile scientific and empirical concepts to set the foundations of the traditional theory of training periodization, meaning the subdivision of the seasonal program into smaller periods and training cycles. Since then, periodization has become an important and indispensable part of training theory. A key feature of the traditional periodization method was the early emphasis on high training volume and a transition to higher training intensity with reduced volume as competition periods approached. A second feature of the method was a reduction in training variation and increase in training specificity throughout the annual cycle.[12,13] The major structural components of a periodized training plan were listed by Matveyev[12] as the microstructure, the mesostructure, and the macrostructure. These, respectively, refer to the structure of separate training sessions or short groupings of sessions (microcycle—ie, a short plan usually lasting about a week); the grouping of a number of microcycles, leading to the realization of a predetermined and specific training or performance goal or goals (mesocycle—ie, a medium-duration plan usually lasting about a month); and larger groupings of mesocycles concerned with longer periods (macrocycle—ie, a long-duration plan usually lasting about half a year or a year).[5,12] These structural components have also been classified into distinct subcategories, such as developmental, shock, regeneration, and peaking/unloading microcycles,[2] or introductory, basic, control, supplemental, preparatory, and competitive mesocycles.[14]

Alternative methods to traditional (or linear) periodization have been proposed, such as nonlinear or undulating, block, fractal, conjugate sequence, or reverse periodization.[7,13,15–17] However, linear and block periodizations (in which the sequencing of accumulation, transmutation, and realization mesocycle blocks purportedly benefits from the favorable interaction of cumulative and residual training effects[7]) have been the main methods studied for strength development[18–20] as well as performance enhancement in a variety of elite sports, including cross-country skiing and biathlon,[21,22] cycling,[23–26] kayaking,[27,28] orienteering,[29] sprinting,[30] swimming,[31,32] and tennis.[33] Depending on the event and the prevailing philosophies in a sport, coaches and athletes may plan for single, double, or multiple peaks for the season. Although the yearly training plan varies considerably between and within sports, according to the athlete's level (eg, developmental or elite), the type of competition (eg, weekly fixtures or major tournaments in team sports versus single-day events or major championships in individual sports), and the recovery needs after each event, there are some common elements. As a rule, most periodization methods share a common distribution of training in phases of general preparation, specific preparation, competition, and transition (Table 1).[2,34] Pyne[31] highlighted other common features of periodized training programs:

- The training program is designed according to the main performance goal for the season.
- Training loads are increased progressively and cyclically.
- The training phases follow a logical sequence.
- The training process is supported by a structured program of scientific monitoring.
- Recovery or regenerative techniques are used intensively throughout the training program.
- Emphasis on skill development and refinement is maintained throughout the training program.

Table 1 **Integrated Periodization Plan for Individual Sports**

	General preparation	Specific preparation	Taper	Competition	Transition/ Off-season/Injury
Training	• High volume • Low to moderate intensity • Low specificity and mixed training modalities (eg, resistance, core stability, cross-training)	• Moderate and high volume • High intensity (eg, race pace) • High specificity • May include specialized training (eg, altitude and/or heat adaptation) • May include domestic and/or international competition	• Low volume • High intensity • High specificity	• Competing in single- or multiple-day events • May involve multiple rounds (ie, heats, semifinals, finals)	• Rest, recover, and regenerate • May include some maintenance training (eg, reduced training, cross-training, cross-education)
Recovery	• Appropriate recovery to maximize training adaptation and goals of general preparation • May involve withholding recovery to maximize adaptation	• Specific recovery support after key sessions, particularly those requiring high levels of skill and/or high-quality training sessions • Recovery may also be utilized to reduce fatigue and soreness in preparation for key sessions	• Recovery can be utilized to minimize fatigue during the taper. This may be useful to decrease the period of time required to taper effectively • Increased recovery may be incorporated to maintain high-intensity training during this period	• Recovery support provided to minimize fatigue and maximize competition performance • Support to manage fatigue around travel and jetlag	• Physical and mental recovery • May include physical therapy for injury recovery/prevention
Nutrition	• Periodized energy and macronutrient intakes toward desired changes in body composition while maintaining adequate energy availability for health and heavy training load • General support for training sessions and recovery between sessions, including strategic timing of nutrient intake around sessions • Where desired, periodic targeted low-CHO availability training to stimulate aerobic adaptations	• Altered energy and nutrient intake to accommodate changes in training focus • Specific support/recovery for key sessions or specialized training (eg, iron, fuel for altitude training) • Further optimization of body composition targets toward taper and competition phase • Practice of specific race nutrition and supplement strategies	• Support for high-intensity training with adjusted energy intake to avoid unnecessary weight gain associated with a reduced energy expenditure • Continued monitoring of optimal body composition for competition phase	• Support for competition/racing, including recovery between multiple rounds in a session and/or multiple competition days • Nutrition and supplementation practices addressing the physiological demands/limitations of the event • Nutrition for travel	• Nutrition recommendations similar to an active to sedentary individual • Some minor weight gain expected or desired • Ergogenic supplements no longer required • Proactive nutrition for injury management/rehabilitation, if appropriate
Psychology	• Motivation, pain and fatigue management, and self-awareness • Goal setting for practice, imagery, and relaxation/activation techniques	• Kinesthetic awareness and control, increased self-efficacy, and emotional management • Use of video, improvements log, and rhythm work	• Optimal arousal, effective focus, and cognitive and emotional self-management • Competition routines, attentional focus, and relaxing/energizing cues	• Trust, flexibility, and confidence • Competition plan, cognitive restructuring tools, and tolerance of ambiguity • Mindfulness	• Effective evaluation and self-care/restoration • Self-identity development • New goal setting
Skill	• High volume and high functional variability of skill repetitions • Skill outcome performance likely to be more inconsistent • Progression should be aggressive but calibrated on optimizing athlete challenge point	• Increased specificity of practice, greater representation of the skills within the competitive performance setting • Overload key skills to promote adaptability and resilience	• Keep in mind reversibility by continuing to practice, but with a reduction in overloading conditions • Less-variable practice conditions can be employed to inflate performer confidence (if required)	• Event can be 1 day or over multiple days: Maintain practice repetition between competitive bouts focused on adapting skill to upcoming opponent or conditions	• Not applicable

- The improvement and maintenance of general athletic abilities is an underlying component of the training program.
- Each phase of the training program builds on the previous phase.

Comprehensive reviews into long-term planning,[5,17] traditional linear periodization,[5,7,15,19] block periodization,[7,35,36] and other periodization methods for elite performance are available elsewhere.[15,17,19,37–40]

Periodized Approach to Other Training Components

Other aspects of training that could benefit from a well-planned or periodized approach include heat adaptation, altitude adaptation, body composition, and physical therapy.

Periodization of Heat Adaptation. In a consensus document, Racinais et al[41] provided recommendations regarding the optimization of exercise capacity during sport activities in hot ambient conditions, mainly for prolonged sporting events. Based on the temporal dynamics of heat acclimatization induction, decay, and reinduction, periodized heat acclimatization strategies were provided for the early season, precompetitive, and competitive periods. A recent case study on the periodized heat acclimation protocol used by 2 elite sailors preparing for the world championships in the heat seems to confirm the validity of the approach.[42] Nevertheless, recommendations from these studies were mainly based on physiological markers of heat acclimatization and deacclimatization, and their impact on competitive sports performance remains uncertain. In a recent review on heat acclimation considerations for elite athletes, Casadio et al[43] indicated that more work is needed to understand how to optimize the periodization of heat acclimatization within an athlete's annual training plan (eg, long- and short-term periodization of heat acclimation, scheduling around an athlete's training and competition calendar, and application in highly trained populations).

Periodization of Altitude Adaptation. In view of the above, it can be suggested that a similar periodized approach to altitude training is also needed. Such an approach should be based on the emerging knowledge of the temporal dynamics of the physiological changes associated with altitude acclimatization, deacclimatization, and reacclimatization, and their impact on competition performance.[44–61] Millet et al[62] proposed different combinations of natural altitude, simulated altitude, and sea-level training to enhance general adaptations and prepare for competition periods at sea level and altitude, but such proposals for altitude use in the annual training plan remain untested in both individual and team sports.

Periodization of Body Composition. Body composition periodization was recently defined as the strategic manipulation of energy intake and energy expenditure between various training phases to reach a targeted body composition range that is optimal for performance (eg, peak power to weight ratio), while minimizing risk to short- and long-term health.[63] A case study featuring the body composition of an Olympic-level female middle-distance runner throughout a 9-year international career showed significant seasonal fluctuations in anthropometric outcomes between training phases. In addition, strong correlations were identified between decreasing skinfold values during peak competition periods and faster 1500-m race times, with only 2 injuries over the 9-year follow-up.[63] Despite a strong conceptual underpinning, more research is needed on the optimal implementation of periodized body composition strategies in short- and long-term planning.

Periodization and Physical Therapy. In an attempt to bridge the gap between sports training and rehabilitation of the injured athlete, overviews of periodization methods and their application to rehabilitation have recently been provided.[37,64] The rationale behind such approaches is that greater knowledge of periodization models can help sport physical therapists in their evaluation, clinical reasoning skills, exercise progression, and goal setting for the sustained return of athletes to high-level competition.

Criticism to Training Periodization

Although most coaches and athletes agree on the perceived benefits and outcomes of a periodized training program (eg, a reduction in the risk of injury, a lower risk of developing symptoms of overtraining, and a better chance of peaking for key competitions), opinions are divided on the process of periodized training. The lack of consensus can perhaps be attributed to the jargon often used around periodization, which sometimes leads to misinterpretation and confusion over nomenclature and makes the concept of periodized training more complicated than it needs to be. Skeptics also point out that the concept is not completely supported by science.[34]

Verchoshanskij, a respected authority on training methodologies, questioned the validity of Matveyev's theory of periodization, considering it outdated and unacceptable for contemporary training, and highlighted 4 "cardinal errors" undermining the theoretical and practical significance of the concept of training periodization[65]:

- A poor understanding of sporting activities and technology of the preparation of elite athletes and the professional know-how of the coaches;
- A primitive evaluation of the methodological concept, which is only theoretical, lacks an objective foundation, is purely speculative, and lacks objectively confirmed practical recommendations;
- Disregard of the biological knowledge; and
- Limited acceptance of related sciences and experimental results on training principles.

Although some of the aforementioned criticisms may be well-founded, Norris and Smith[5] considered that the concept of periodization has grown beyond the initial specific recommendations of Matveyev.[12] Without denying the historical value of the periodization philosophy or the substantial contributions made by eminent training theorists, Kiely[13] suggested that periodization dictates should be understood as hypothetical and tradition-driven assumptions rather than evidence-led constructs. In this context, coaches and athletes should shift from the preordained training structures toward a philosophy characterized by an adaptive readiness to respond to emerging information. Effective planning may be perceived as the implementation of sensitive and responsive learning systems designed for the early detection of emerging threats and opportunities. More recently, Kiely[66] indicated that realigning periodization with contemporary stress theory provides an opportunity to recalibrate training planning models with contemporary scientific insight and progressive coaching practice.

Loturco and Nakamura[67] recently suggested that the periodization concept should be revisited, in view of a purported low rate of effectiveness to control and attain an athlete's peak performance. They also highlighted the need to develop more applied, effective, and realistic methods of training for athletes who compete several times per year and need to maintain high performance levels throughout a complete macrocycle. Such criticisms, however, seem to be directed toward rigid and inflexible concepts of the classic periodization structure (eg, the necessity to progress from basic to particular aspects of the specific sports performance within the same training cycle). When an integrated periodization approach is used, based on current scientific research and understanding, this practice reflects a philosophical need for planning and addressing the core components of athletic preparation to maximize and optimize future performance, rather than adherence to a central methodology.[5]

Recent criticism also came from a comprehensive review on the conceptual and methodological issues surrounding empirical research on training periodization.[68] Only 42 randomized or randomized controlled trials were identified that met stringent inclusion and exclusion criteria. Problems emerged in the following domains:

- Conceptually, periodization and variation were being used interchangeably in research.
- No empirical research tested predictions concerning direction, timing, and magnitude of adaptations.
- More than 95% of papers were mostly unidimensional—that is, focusing almost exclusively on the "physical" aspects of performance.
- Empirical research on long-term effects was absent (no study lasted more than 9 mo).
- Controlling for confounding factors, such as nutrition, supplementation, and medication, was largely ignored.
- Data analysis was biased as dispersion in responsiveness to experimental protocols was ignored when discussing the findings.

The work by Afonso et al[68] highlights the importance of considering periodization from a multidimensional perspective if coaches and scientific staff are to appropriately schedule training load, a limitation that this review tries to overcome.

Periodization in Team Sports

A periodized approach in the long- and short-term manipulation of training stress and recovery is thought to be essential for optimal athletic performance and success in competition. Individual sport athletes usually achieve fitness and performance peaks through months of consistent training followed by a period of tapered training, culminating with a single or a limited number of important races or championships.[69] The physiological, psychological, and performance benefits of such a peaking strategy are well established for endurance[70,71] and strength-oriented individual sport athletes.[72] In the best interest of peak performance at major competitions, these athletes can afford to exhibit subpar performances and even miss competitions that do not fall within the scope of their major goals. By contrast, team sport athletes in general, and soccer players in particular, usually need to perform at a high level week after week if they want to be in contention for the championship at the end of the competitive season.[69]

Designing periodized training programs for team sports athletes poses unique challenges and difficulties. Indeed, athletes (eg, soccer players) are required to work on multiple aspects of their individual fitness and physical readiness to perform, while concurrently participating in extensive technical and tactical team training sessions to prepare for upcoming matches, as well as extended periods of competition itself (see Table 2).[73] In this context, proper manipulation of the total training stress, both over the training and competition season and within short-term training cycles, is required for success. Moreira et al[74] examined the training periodization pattern of a professional Australian football team during different phases of the season, using the session rating of perceived exertion (s-RPE) method. Higher training loads and session durations were performed for all training types during the preseason compared with in-season, but the in-season games were of greater load and intensity than preseason games, and the overall distribution of training intensity was similar between the preseason and in-season.

Ritchie et al[75] quantified training and competition load across an entire season in an elite Australian football team, using global positioning system tracking and s-RPE. The total s-RPE load was greater during the preseason, where most of the load was obtained via skills and conditioning. A large reduction in the s-RPE load occurred in the last preseason block, consistent with a taper phase also described in other football codes, such as soccer,[76,77] rugby league,[78,79] and rugby sevens[80,81] and also in elite basketball.[82] In-season, half the total load came from games, and the remaining half from training—predominantly skills and upper-body strength training. Total distance, high-intensity running, and acceleration–deceleration activity showed large to very large reductions from preseason to in-season, whereas changes in mean speed were trivial across all blocks.[75] This work highlights the importance of considering periodization from a multidimensional perspective if coaches and scientific staff are to appropriately schedule training load.[68] Periodization patterns in weekly planning have also been described by means of s-RPE and heart rate in elite basketball players during the competitive season, including 1 or 2 matches per week. Coaches spontaneously provided an unloading phase during the competitive weeks, irrespective of the number of weekly games played.[83] These studies indicate that team sport players often train hard to get fit in the preseason, taper their training to reach a fitness peak before the competitive season starts, and then try to maintain their fitness through moderate training and match participation in-season.

Although attempts have been made in soccer to substantiate the idea of periodizing training into phases, scientific evidence to support its application is still scarce. Mara et al[84] studied the variation in training demands, physical performance, and player well-being according to training phase in a female soccer team, as well as the relationships among these variables throughout a national league season. As in the aforementioned Australian football studies, training demands (eg, total running distance, high-speed distance, and acceleration counts) during training sessions declined across all phases from preseason to late season. Although endurance capacity and well-being measures did not change across training phases, acceleration and 25-m sprint performance progressively declined toward the end of the season. Fessi et al[85] reported that tapering training weeks before important or especially difficult soccer matches led to increased total running distance, intense running, high-intensity running, and total number of intense activities during match play.[85] Unfortunately, these results could not be dissociated from potential confounding factors, such as mental fatigue, pacing strategies, current match result, or tactical considerations. Consequently, the results of repeated tapering before soccer matches should be interpreted with caution.

Mallo[86] implemented a block periodization training model in a professional soccer team during 4 consecutive seasons and reported that the highest team performance in competition was achieved during the realization blocks, in particular when the team played

Table 2 Integrated Periodization Plan for Team Sports

	General preparation	Specific preparation/ Precompetition	Main competition/ Regular season	Play-offs/Finals	Transition/ Off-season/Injury
Training	• Aerobic conditioning • Resistance training • Team-based activities supported by individual sessions • May include specialized training (eg, altitude and/or heat adaptation)	• Match play • Sport-specific technical–tactical training	• Weekly/twice-weekly match fixture • Recovery from match • Specific conditioning between matches to maintain fitness and peak for key matches • Preparation for match	• Same as main competition/regular season phase with major fitness/ performance peak	• Individual maintenance conditioning • Corrective surgery and/or injury rehabilitation
Recovery	• May involve withholding recovery to maximize adaptation • Cold water immersion may be avoided after resistance training sessions	• Increase in recovery between training sessions in preparation for specific training sessions • Recovery following preseason matches (eg, active recovery, cold water immersion, contrast water therapy, massage, compression garments)	• Postcompetition/event recovery (same as specific preparation/ precompetition phase) • Between competition/ event recovery (same as specific preparation/ precompetition phase)	• Postcompetition/event recovery (same as specific preparation/ precompetition phase)	• Psychological recovery • Increase positive mood state
Nutrition	• Appropriate energy and micronutrient intake to support body composition goals, including increase in lean body mass and loss of excess body fat • General support for training and recovery between training sessions, including strategic timing of intake around sessions • Potential for targeted use of training with low carbohydrate availability to enhance adaptations to aerobic training • Focus on hydration during hot weather training	• Continuation of nutrition goals from the preparation phase • Practice of match nutrition and supplement strategies	• Prematch and during-match strategies of nutrition and performance supplements to address the specific needs of each player's position or style of play • Postmatch recovery • Maintenance of body composition achieved in general preparation and precompetition phases • Nutrition for travel for away matches	• Same as main competition/regular season phase • Potential inclusion of considerations for warm/hot weather	• Minimization of negative changes in body composition • Proactive nutrition for injury management/ rehabilitation, if appropriate
Psychology	• Motivation, pain and fatigue management, and self-awareness • Goal setting for practice, imagery, relaxation/ activation techniques • Individual engagement, team communication	• Kinesthetic awareness and control, increased self-efficacy, emotional management, and learning style awareness • Use of video, improvements log • Promoting contact among players, group discussions	• Optimal arousal, effective focus, cognitive and emotional self-management, competition routines, attentional focus, and relaxing/energizing cues • Promoting uniformity, togetherness, group initiative, collaboration activities	• Trust, flexibility, and confidence • Competition plan, cognitive restructuring tools, tolerance of ambiguity, and team confidence • Mindfulness, interpersonal trust • Empowering team decision-making, creative use of talents	• Effective evaluation and self-care/ restoration • Self-identity development • New goal setting
Skill	• High volume and high functional variability of skill repetitions • Skill outcome performance likely to be more inconsistent • Greater volume of less structured game play	• Increased specificity of practice and game play (specific tactical concepts practiced) within the competitive performance setting • Increased cognitive engagement expected through tactical learning	• Specific tactical and technical preparation for match (including own team rules and introducing awareness of the opponents' style of play) • Off-field/court preparation more prevalent (eg, video preview and review)	• Same as main competition/regular season phase	Not applicable

against low- and middle-ranked teams. It was suggested that block periodization can be considered an alternative training design for professional soccer teams.[86]

In addition to the preseason and competition season, team sports also involve a transition (ie, off-season) phase. During this transition phase, which typically lasts 4 to 6 weeks, players usually are away from the team discipline and supervised training, and even if they individually engage in some form of exercise, some degree of detraining will certainly take place. A detailed description of the anatomical, physiological, and performance consequences of training cessation or insufficient training in athletes over time is beyond the scope of this article, and interested readers are directed to previous reviews on the topic.[87,88] Strategies aiming to reduce the severity of detraining would be worthwhile for the less active athlete during the transition period. These strategies generally include performing either a reduced training program or an alternative form of training (ie, to cross-train).[89] In line with the above, Silva et al[90] recently described the physiological changes that occur during the transition period in soccer players (ie, small to moderate negative changes in body composition, a moderate decline in sprint performance with and without changes of direction, small to moderate decrements in muscle power, large decrements in maximal oxygen consumption and time to exhaustion, and moderate to very large impairments in intermittent-running performance) and addressed the issue of utilizing the transition period to lay the foundation for the succeeding season. These authors considered that the transition period should be viewed as a "window of opportunity" for players to recover and to "rebuild" for the following season, and they recommended a "minimum effective dose" of training to attenuate the loss of endurance and neuromuscular performance, reduce muscle strength imbalances, and improve the players' ability to cope with the elevated training demands of preseason training, thus reducing the risk of injury.[90]

In summary, it seems clear that a periodized approach to the season could be a useful strategy in soccer and other team sports. A preseason characterized by progressive overload training and culminating with a 2- to 3-week taper is a well-supported strategy.[77–81] Once the competitive season starts, how a team maintains the peak fitness levels achieved during the preseason periodized program will depend on factors such as time between games, travel, competitiveness of the opponents, injury, minutes of match play, and physiological adaptations to competition, recovery, and training of individual players. Integrating these variables into the in-season periodized training plan for the team to retain or further improve early-season fitness and performance levels can also be an effective strategy.[69,85,86,91] The main aim of the off-season should be recovery and regeneration, but a maintenance training program is recommended to avoid excessive detraining and to facilitate subsequent adaptation during the preseason.[89] Based on this framework, further investigation of training periodization in team sports is warranted.

Strategic Periodization: Team sports coaches often struggle to determine the most appropriate training loads to prescribe in-between matches during the competitive season. Multiple factors, including the quality of the next opponent, the number of days available to train and recover between matches, and travel associated with away games, influence the between-match training periodization.[92] Strategic periodization (or tactical periodization) is an emerging concept in the context of team sports. It has been defined as the intentional peaking for matches or events of perceived greatest priority or difficulty throughout a competitive season.[93] This is typically achieved by means of deliberate manipulation of training loads and recovery in the lead-up to targeted matches. Effective implementation of strategic periodization is considered a useful tool in managing the heavy travel schedule, fatigue, and injuries that often accompany a sports team throughout a competitive season.[94]

Cormack[95] developed a periodization model for an Australian football league team based on the number of training days between matches and the effect of interstate travel, and suggested several factors that can affect the success of an in-season periodization plan, such as the coaches' understanding of the training process, the prescription and monitoring of the volume and intensity of skill training sessions, and the balance between training load and recovery. Expanding on these ideas, Kelly and Coutts[92] proposed a model to guide in-season training loads in team sports. The model allows users to predict match difficulty by categorizing and scoring 3 key factors—namely, the level of the opponents, training days between matches, and match location. The weekly training load is subsequently planned using the s-RPE method and is based on match difficulty, which is reassessed on a weekly basis. Training is also monitored through s-RPE, and the planned training load is compared with the load that is actually performed. This model should allow users to guide the prescription of training throughout the competitive season and ensure the team maintains optimal fitness levels leading into key matches.[92]

Robertson and Joyce[93] developed a match difficulty index for use in rugby, based on the influence exerted by external factors on match outcomes. The opponents' previous- and current-year rankings, as well as the game location, were the most influential external factors in determining the difficulty of a match. Building on their previous model, Robertson and Joyce[94] recently provided a strategic periodization framework that team sport organizations can use to evaluate the efficacy of such plans. Match difficulty index models were developed on the basis of fixed factors available to the teams prior to the commencement of the competitive season (ie, match location, the opponents' previous-season rank, and between-match break length), as well as dynamic factors obtained at monthly intervals throughout the in-season (ie, the opponents' current-season rank, the difference in ladder position between both teams, the number of players changed from the previous match or matches, the number of first-year players selected in the side, and the team form based on the number of wins scored by the team in the previous weeks). The opponents' previous-season rank was the strongest indicator of match difficulty across models, whereas the influence of away games on match difficulty became stronger as the season progressed. In addition, the number of matches won by a team over the past 4 attempts represented the most appropriate definition in defining team form.[94]

A match difficulty index can be a useful tool to evaluate the long- and short-term efficacy of strategic periodization plans in team sports and can inform a periodized approach to training. However, future research should extend these concepts to other team sports, such as soccer; develop sport-specific match difficulty indices; and assess the impact of additional fixed and dynamic factors for model development.[94]

Strategic periodization should not be confounded with so-called tactical periodization, a soccer training methodology that is gaining popularity but which lacks evidence-based support. The key principle behind the method is that the game of soccer should always be learned and/or trained respecting its logical structure, which revolves around the "4 moments of the game" (ie, defensive organization, offensive organization, defense to offense transition, offense to defense transition). Accordingly, at least 1 of these 4 moments of the game is always present in every training exercise.

Every game action occurs in one of these moments and involves a decision (tactical dimension) and an action or motor skill (technical dimension) that requires a particular movement (physiological dimension) and is directed by volitional and emotional states (psychological dimension); furthermore, these dimensions are never trained independently. Readers are referred to Delgado-Bordonau and Mendez-Villanueva[96] for further information on this method.

Periodization of Recovery

Periodization of recovery has become an important consideration for athletes and coaches, and the role of recovery in adaptation is currently one of the more controversial and divisive aspects of recovery theory and practice. Fatigue and muscle damage resulting from training and competition may influence training quality and/or performance over subsequent days. For this reason, recovery is often viewed as an important means of returning the body to a homeostatic state. However, overall adaptation to training and maximizing performance at critical periods are the ultimate goals for the elite athlete.

Structuring recovery within the training plan to appropriately distribute both training stress and fatigue/soreness is necessary to maximize performance and adaptation. The manipulation of recovery with the training program may incorporate one or all of the below themes:

- Withholding recovery at certain times, most commonly in the general preparation phase, to maximize adaptation to training (chronic recovery);
- Utilizing recovery during the specific preparation phase to *prepare* for certain training sessions (acute recovery);
- Utilizing increased recovery to decrease acute fatigue during the competition phase (acute recovery); and
- Incorporating recovery during travel, recovery from injury, and to manage psychological stress (acute and chronic recovery).

Although much of the available evidence suggests that various proactive recovery strategies (eg, hydrotherapy, whole-body cryotherapy, massage, and compression garments) may hasten recovery of exercise performance following *acute* strenuous exercise,[97–103] there are many unanswered questions when considering adaptation and *chronic* recovery exposure.[104–106] The analysis of the impact of acute and chronic recovery may aid in the periodization of recovery practices, in particular one of the most popular strategies: cold water immersion (CWI).

Acute Versus Chronic Effects of Recovery Strategies

Essentially, there are 2 opposing theories on the use of recovery, in particular CWI, in relation to the adaptation process. One theory is that recovery should enable athletes to train more effectively in their subsequent training session, which has been proposed to translate into greater training adaptations and improved performance in the long term. However, training theory suggests that postexercise fatigue and inflammation is necessary to promote longer-term training adaptation and improvements in performance. It is not currently known if performing hydrotherapy will "dampen" the anticipated training benefits.[104,105]

An understanding of the mechanisms by which CWI may influence recovery, and therefore adaptation, is useful to enhance the ability to periodize recovery within the training program. While a detailed discussion is beyond the scope of this review, the primary mechanisms include a decrease in tissue temperature, increase in buoyancy, increase in hydrostatic pressure, decrease in muscle perfusion, decrease in nerve conduction velocity, and decrease in permeability of cellular, lymphatic, and capillary vessels.[107] Consequently, these mechanisms may result in anti-inflammatory effects, decreased perception of fatigue, increased efflux of metabolic waste products, decreased edema, decreased recovery time and secondary tissue damage, and increased reabsorption of interstitial fluid (for review, see Tipton et al[107]). These physiological and psychological effects have the potential to influence both acute and chronic recovery.

Acute Recovery. The effects of recovery on acute performance often demonstrate mixed results despite a number of reviews and meta-analyses highlighting small but positive effects on performance.[102,108] This may be due in part to thermal and cardiovascular effects that are influenced by individual responses in body temperature and blood flow.[109] Further variability may be the result of water immersion protocols (temperature, duration, and depth) and the individuals' body composition.[109] Although there are multiple influences on the effectiveness of CWI, it is generally considered that when CWI protocols are appropriate, performance is acutely enhanced.

Chronic Recovery. Much of this speculation about the chronic use of hydrotherapy recovery techniques has come from a small number of studies. In a study by Yamane et al,[110] subjects performed regular CWI following cycling or handgrip exercise 3 to 4 times a week for 4 to 6 weeks. The authors concluded that microdamage and metabolic alterations may be negatively influenced by CWI, due to the prevention of muscle hyperthermia, which may have interfered with myofiber regeneration. A number of methodological limitations, however, question the study findings and applicability to the sporting population: muscle temperature was not measured, so the degree of muscle cooling is not known; subjects were few and untrained; water temperatures were lower and immersion durations longer than those typically used by athletes; and performance tests were not representative of athletic performance. In a subsequent study by the same group, untrained male subjects performed wrist-flexion exercises 3 times a week for 6 weeks. Subjects who immersed their experimental forearms in cold water after exercise showed reduced wrist-flexor thicknesses, maximal muscle strength, brachial artery diameter, and local muscle endurance increment.[111]

In contrast with the above, Howatson et al[112] examined the influence of CWI on maximum voluntary contraction, perception of muscle soreness, creatine kinase, muscle girths, and range of motion following 2 bouts of drop jump exercise separated by 14 to 21 days. No significant differences were observed between CWI and control, indicating no effect on adaptation. Similarly, Broatch et al[113] reported no effect of CWI on molecular signaling pathways associated with regulation of mitochondrial biogenesis phospho-p53 and peroxisome proliferator-activated receptor-γ coactivator-1α mRNA after 6 weeks of cycling sprint interval training. Furthermore, no changes were observed in peak aerobic power, maximal oxygen consumption, and 2-km time trial performance. The contention that chronic CWI may blunt training adaptation in athletes is, thus, not supported by the available research.

Roberts et al[106] compared the effects of CWI and active recovery on changes in muscle mass and strength after 12 weeks of strength training, as well as the effects of hypertrophy on signaling pathways and satellite cell activity after acute strength exercise in physically active men training 2 days per week. Cold water immersion attenuated long-term gains in muscle mass and strength and blunted the activation of key proteins and satellite cells in skeletal muscle up to 2 days after strength exercise. The authors concluded that athletes should reconsider the use of CWI for recovery. However, as the participants were untrained and were training only two times per week, the relevance of this study to elite athletes is questionable. Furthermore, Fröhlich et al[104] investigated CWI of a single leg over a 5-week strength training period. Small negative effects were observed for changes in 1-repetition maximum (RM) and 12RM at the completion of the training phase in the leg that underwent CWI. Again, the participants were not elite athletes, and the changes observed were very small.

Finally, some studies have examined the use of ice or cold packs postexercise on aspects of muscle recovery. While ice/cold packs may differ from CWI in both performance outcomes and mechanism of action, the results of these papers have been used to question the role of hydrotherapy in adaptation to training. Nemet et al[114] exposed 12 elite junior handball players to 2×15-minute cold pack applications to the legs immediately following 4×250-m running efforts. Cold pack application resulted in significant decreases in circulating growth factors and inflammatory cytokines interleukin-1β (IL-1B), interleukin-1 receptor antagonist (IL-1ra), insulin-like growth factor 1 (IGF-1), insulin-like growth-factor-binding protein 3 (IGFBP-3), insulin-like growth-factor-binding protein 1 (IGFBP-1) during recovery. The authors concluded that local ice therapy resulted in a greater decrease of both proinflammatory and anti-inflammatory cytokines and a greater decrease in anabolic hormones.

Halson et al[105] investigated the effects of CWI 4 times per week or passive recovery over 7 days of baseline training, 21 days of intensified training, and an 11-day taper. Cyclists in the CWI group had an unclear change in overall 4-minute power relative to control, although mean power in the second effort relative to the first was likely higher for the CWI group relative to control. The effect in mean sprint power in the CWI group was likely beneficial compared with control, but differences between groups for the 10-minute time trial were unclear. This is one of the only studies that has investigated recovery in a well-trained population, incorporating practical use of CWI in athletes undertaking a considerable amount of training. Results suggest that hydrotherapy does not hinder adaptation to training and may indeed enhance a number of aspects of cycling performance.

The effect of regular postexercise CWI (3 sessions per week of endurance training for 4 wk) on muscle aerobic adaptations to endurance training has been recently examined.[115] Data collected via muscle biopsies revealed that repeated CWI enhances p38 mitogen-activated protein kinases (p38 MAPK), adenosine monophosphate-activated protein kinase (AMPK), and possibly mitochondrial biogenesis. As performance was not measured in this study, the implications of these adaptations on athletic performance are unclear.

Although high-quality scientific data in the area of chronic recovery and adaptation are scarce, available research suggests that if practitioners wish to take a conservative approach to recovery, withholding CWI after resistance training sessions would be recommended.

Considerations for Periodization of Recovery

Although evidence regarding the effects of recovery on adaptation is limited, based on the above information, periodizing recovery to maximize the positive benefits of training stress, fatigue, and soreness appears warranted. Furthermore, there is no "one-size-fits-all" approach, and consideration of the sport and its demands, as well as the individual needs of the athlete, should be at the forefront when periodizing recovery. Some of the key themes are outlined below:

- Withholding recovery at certain times, most commonly in the general preparation phase, to maximize adaptation to training (chronic recovery): As the fatigue induced during training is a major influence of adaptation to training, many athletes intentionally increase training load to induce fatigue, then provide adequate recovery to induce adaptation. There may be phases of training where higher levels of fatigue are acceptable, and therefore, recovery may not be essential or indeed may be harmful. This is most often seen in the early general preparation phase, where there is adequate time to reduce fatigue prior to competition. However, when failure to adapt occurs due to high training loads and limited recovery, a state of nonfunctional overreaching or overtraining may develop,[4] and thus, careful monitoring of fatigue is necessary.
- Utilizing recovery during the specific preparation phase to *prepare* for certain training sessions (acute recovery): In sports involving a high skill component or when high-intensity, high-quality training sessions are required, it is suggested that the athletes have minimal fatigue to optimize the quality of training. In this regard, recovery can be incorporated into the specific preparation phase to maximize the athletes' ability to prepare for certain training sessions. Specifically, athletes participating in sports involving eccentric muscle damage and/or physical contact may experience increased levels of damage and soreness, which may require enhanced recovery needs.
- Utilizing increased recovery to decrease acute fatigue during the competition phase (acute recovery): As outlined earlier, there is evidence to suggest that acute performance may be positively influenced by recovery. For this reason, recovery is often highlighted during the competition phase. Again, it is important to consider the sport itself and the nature of the competition. When competition occurs frequently, such as in elite soccer and other team sports that are played 1 to 3 times per week, the athlete may benefit from increased recovery. However, in some individual sports, such as swimming, where major competitions may be 1 to 3 times per year, there may be a lesser demand for recovery for these athletes.
- Incorporating recovery during travel, after an injury, and to manage psychological stress (acute and chronic recovery): Many elite athletes are required to travel extensively for competition, which can increase fatigue both acutely and over a season.[116] Recovery strategically placed around periods of travel may aid in managing fatigue, especially around competition. While there is minimal scientific evidence, anecdotal evidence suggests that for athletes who are at a higher risk of injury (either because of the type of sport they are involved in or because they have experienced previous injuries), additional recovery may help reduce the risk of injury and enhance recovery from existing injuries.

From a psychological perspective, CWI may have a positive effect on mood, as evidenced by increases in dopamine, serotonin, and β-endorphins.[107] This may be important during periods of high psychological stress, such as during competition. Finally, many athletes report increased subjective recovery and reduced soreness with appropriate recovery, and, as such, strong belief effects for the role of recovery in performance may be held by some athletes. The effect of this belief in recovery on actual performance may not be clear; however, as belief effects can be extremely powerful, this should not be discounted as an important influence on performance in elite athletes.[117]

Summary

In summary, recovery strategies, and CWI in particular, can influence both acute and chronic performance and adaptation. Recovery may be withheld during the general preparation phase, increased during specific preparation, and further increased during competition and periods of increased recovery needs. Careful consideration of the use of recovery in different phases of the training program may result in optimal performance outcomes for individual and team sport athletes (see Tables 1 and 2).

Dietary Periodization

Sports nutrition has evolved over the past 4 decades from a series of disjointed ideas and one-size-fits-all guidelines into an evidence-based science promoting integrated and personalized practices. Whereas early efforts were based on static recommendations focused on the fuel needs for endurance athletes, contemporary sports nutrition guidelines are event specific, suited to each individual athlete, and periodized to meet differences in goals across time, ranging from a training microcycle to a whole sporting career.

Although a single or unified definition of the term *dietary periodization* does not exist, there are at least 4 different themes that can be explored to justify a strategic manipulation of nutrient intake between and within days to optimize athletic performance. These can be illustrated by the following examples:

- Periodizing energy and nutrient intake to track changing needs or goals of training and competition;
- Periodizing strategies that increase capacity for fuel utilization from one substrate (eg, fat) to another (eg, carbohydrate [CHO]) with the goal of harnessing increased capacity from both systems;
- Alternating between 2 often opposite strategies of providing nutritional support to promote optimal performance and withholding nutritional support to increase the training stimulus or enhance adaptation; and
- Arranging nutrient intake over the day, and in relation to training sessions, to enhance the metabolic interaction between exercise and nutrition.

Periodizing Nutrition to Track Changing Needs

Although athletes may set their goals to span a longer period, such as an Olympic cycle or the years of a college scholarship, the yearly training plan provides a convenient template to illustrate the changes in nutritional priorities and strategies across different phases of training and competition. Tables 1 and 2 illustrate some of the typical priorities or nutritional practices included in the general preparation phase, specific competition preparation, competition itself, and transition or off-season between phases for individual athletes and team sport athletes. Changes in the type, volume, and intensity of training clearly create major differences in energy needs, as well as requirements for CHO (eg, to meet muscle fuel needs), protein (eg, to promote adaptation), fluid (eg, to replace sweat losses), and some micronutrients (eg, iron for altitude training). Manipulations in body composition, which require alterations in energy intake and potentially in protein intake, may need to be factored into the general preparation phase, leaving sufficient time to gradually achieve optimal competition physique (body fat and lean mass goals) while supporting the training load and providing adequate energy availability to support health.[118] The organization of the type and timing of nutrient intake to optimize adaptation or recovery around specific sessions or training phases (see Tables 1 and 2) must also be factored into the total energy and nutrient plan, as well as incorporated from day to day as appropriate.

According to the athlete's event or sport, a range of nutritional strategies may be undertaken around a competition to address the physiological or biochemical factors that would otherwise limit performance or cause fatigue. These include protocols to provide adequate fuel availability or maintain hydration, consideration of gastrointestinal comfort, and the use of evidence-based supplements. According to the frequency and number of competition events undertaken by an athlete, these strategies may be an occasional or significant part of the athlete's total nutrition plan. In any case, the athlete should include some practice with intended event nutrition protocols during the competition preparation phase to identify successful practices and fine-tune the plan of implementation. Real-world competition often involves a combination of nutrition practices or complicated timetables of use;[119] thus, an individualized and practiced nutrition plan must be developed.

Historically, the off-season was a time of significant detraining and deconditioning, with athletes reducing or refraining from training while indulging in less healthy eating practices and/or increased alcohol consumption. In modern sport, however, many athletes or their teams now instigate a more judicious approach to the phase between seasons to avoid spending significant amounts of the following season's general preparation time regaining the previous level of conditioning. Specific mention must be made of the nutritional support for the injured athlete or the athlete recovering from surgery. Previously, this period was also a time of significant loss of fitness and gain of body fat, and although athletes now try to reduce energy intake to avoid a situation of energy surplus, a more proactive approach to injury rehabilitation is to focus on the maintenance of lean mass and the support of the repair and regeneration of damaged tissues.[120] This approach may involve a thorough organization of energy intake that is commensurate with the change in energy expenditure, higher intake of protein that is well spread across the day, and consideration of nutrients and supplements that might address the health of bone, collagenous tissues, and muscle.[120,121]

Periodizing Fuel Systems to Build Metabolic Flexibility

In many events, competitive success is determined by the muscle's ability to optimize adenosine triphosphate production to meet the requirements of the exercise task; this reflects both the size of the available substrate pools and the muscle's "metabolic flexibility," defined as the ability to integrate or transition between substrates in response to hormonal and/or contractual stimuli.[122] In the case of continuous, prolonged (>90 min), endurance-based exercise, depletion of the body's relatively limited CHO stores is a common cause of fatigue or suboptimal performance.[123,124] Although well-trained athletes have an enhanced capacity for fat oxidation, their ability to use their relatively large fat stores as an exercise substrate is clearly not maximized because it can be further upregulated by switching to a low-CHO, high-fat diet (LCHF). Indeed, short-term exposure (~5 d) to a diet providing <20% energy from CHO and 60% to 65% from fat, while continuing to undertake both high-volume and high-intensity training sessions, has been shown to achieve a robust retooling of the muscle to increase the mobilization, transport, and oxidation of fat, even in the face of strategies to acutely restore high CHO availability, such as glycogen supercompensation and CHO intake during exercise.[125–127]

Although the strategies needed to prime each of these fuel systems are polarized, it has been hypothesized that a sequential implementation might be able to harness enhanced capacity from both substrates. Specifically, undertaking the briefest effective adaptation to a high-fat diet before reestablishing high CHO availability in the 24 hours prior to, and during, an endurance or ultra-endurance event might improve metabolic flexibility and performance if it could combine high CHO stores with an ability to use them more slowly due to increased fat utilization. However, researchers have failed to find that this fat adaptation/CHO restoration protocol enhances the performance of subsequent prolonged exercise, despite achieving remarkable reductions in muscle glycogen use (for review, see Burke[128]). One apparent explanation for this outcome is that, rather than sparing glycogen utilization, fat adaptation causes an impairment of CHO oxidation due to a reduction in glycogenolysis and downregulation of the activity of the pyruvate dehydrogenase complex.[129] The consequences of reduced efficiency of CHO utilization within the citric acid cycle are likely to manifest in a reduced ability to support the adenosine triphosphate requirements for exercise at higher intensities. Indeed, a study of the fat adaptation/CHO restoration periodization model on performance in a 100-km cycling time trial found the most significant effect to be an impaired ability to undertake sprints at >90% peak power output/~80% maximal oxygen uptake.[130] This outcome, representing a reduction rather than improvement of metabolic flexibility, would likely translate into reduced performance of shorter endurance events conducted at these exercise intensities (eg, half-marathon; 40-km cycling time trial), as well as an impaired ability to undertake the critical activities within most longer endurance/ultra-endurance sports events (ie, a breakaway, a tactical surge, attacking a hill, or sprinting to the finish line), which determine the overall outcome. Understandably, the interpretation of these decade-old data was that dietary periodization involving a brief fat-adaptation/CHO restoration could not be recommended for the typical endurance/ultra-endurance event in which a range of exercise intensities are required, even for brief periods; however, events involving only low-to-moderate-intensity activity might benefit from further investigation of the protocol.

The recent reemergence of interest in the ketogenic LCHF diet (<50 g/d CHO, 75%–80% fat, and moderate protein intake) has also raised further possibilities of a periodized integration of otherwise-polarized strategies for promoting fat utilization and CHO oxidation. Possibilities suggested within lay discussions of the ketogenic diet include chronic adherence to the LCHF diet, with the introduction of CHO only on race day, in preevent and during-event feeding,[131] or block periods (eg, 3–4 wk) of adaptation to the LCHF diet within a diet otherwise constructed around higher CHO availability, in a manner similar to altitude training. In the latter case, the prevailing theory is that benefits achieved during the adaptation phase will persist and be apparent once a return to "normal" CHO availability is combined with a precompetition taper. Despite fervent discussions of these ideas on social media platforms, there is no research literature on which to judge their merits. In addition to downregulation of muscle characteristics related to CHO utilization, the chronic effect of very restricted intake of CHO on intestinal CHO uptake would also need to be considered.[132] It is possible that the sudden reintroduction of CHO on race day might exceed the downregulated capacity of gut glucose absorption via sodium-glucose-linked transporter-1 (SGLT-1) transporters, increasing the risk of gastrointestinal discomfort as well as interfering with the provision of additional muscle substrate. Studies are needed to explore these and other variations of the periodization of fat adaptation and high CHO availability.

Nutrition for Adaptation Versus Recovery/Performance

Increased ability to study cellular responses to exercise and nutrient stimuli has provided the insight that, across many areas of sports nutrition, the processes related to adaptation may be divergent from those that promote recovery/performance. In an admittedly simplified overview, many processes that promote recovery from exercise to restore homeostasis and exercise capacity are based on the provision of nutrient support. Meanwhile, in some areas, the absence or deliberate withdrawal of nutritional support may increase exercise stress and/or promote the signaling pathways that lead to a remodeling of the muscle and other physiological systems to create a faster, stronger athlete. Consequently, some nutritional strategies may be suited to supporting the athlete to compete optimally or to complete key training sessions as well as possible (ie, "train harder"). Conversely, the opposite strategy may stimulate greater adaptation to the same exercise stimulus and could be integrated into training phases (ie, a "training smarter" approach). These concepts may explain the research literature around the use of antioxidant and anti-inflammatory nutrients; some studies have shown that supplementation can impair training adaptation and long-term performance via a chronic blunting of adaptive processes that involve redox-sensitive signaling pathways, whereas others report enhancement of acute recovery via a reduction in oxidative/inflammatory damage (for review, see Braakhuis and Hopkins[133]). Similarly, there is evidence that although fluid intake enhances endurance performance in the heat,[134] deliberate dehydration during training sessions may enhance the physiological and cardiovascular processes of acclimatization.[135] Nevertheless, the area in which most investigation has been undertaken around the theme of strategic addition or withholding of nutritional support involves the manipulation of CHO availability.

Whereas the earliest sports nutrition guidelines recommended a "high CHO" diet for all athletes, with targets provided as absolute amounts of CHO (regardless of an athlete's size or exercise load) or as percentage of energy intake (regardless of the total energy intake),[136] contemporary guidelines recognize that CHO intake should be seen in the context of "CHO availability," in which the daily amount and timing of CHO intake are compared with muscle fuel costs of the training or competition schedule. Scenarios of "high CHO availability" cover strategies in which body CHO supplies can meet the fuel costs of the exercise program, whereas "low CHO availability" considers scenarios in which endogenous and/or exogenous CHO supplies are less than muscle fuel needs. The current guidelines[137] recommend that high CHO availability should be achieved on days in which competition or high-quality/demanding training sessions will benefit from optimal fueling of muscle and central nervous system function (ie, optimization of work rates, perception of effort, skill and technique, and concentration and mental processing). On these occasions, CHO intake should be integrated with other dietary goals to achieve adequate muscle fuel (from glycogen stores supported by additional exogenous CHO supplies), as well as to support other body processes requiring CHO (eg, immune system support). Targets will consider both the total amount of CHO and its timing of intake around the workout or event. Competition strategies will need to address the practical considerations for consuming nutrients around exercise (eg, event rules, opportunity to consume foods/drinks, and availability of supplies). Some training sessions should mimic these conditions to practice the behaviors and to "train the gut" (ie, enhance rates of gastric emptying or intestinal absorption of CHO, increase tolerance/gut comfort).[138] On days when training is of lower volume and/or intensity, it may be less critical to meet such targets or practice these strategies. The practical manifestation of this approach is that each athlete would vary his/her CHO intake from day to day according to the fuel needs of their exercise load and the importance of optimizing the CHO contribution toward this.

More recently, it has been recognized that CHO and, in particular, muscle glycogen, play important direct and indirect roles in regulating a muscle's adaptation to training. Specifically, undertaking a bout of endurance exercise with low muscle glycogen stores produces a coordinated upregulation of key cell signaling kinases (eg, AMPK, p38 MAPK), transcription factors (eg, p53, peroxisome-proliferator-activated receptor delta [PPARδ]), and transcriptional coactivators (eg, PGC-1α).[139,140] A number of mechanisms underpin this outcome, including increasing the activity of molecules with a glycogen-binding domain, increasing free fatty acid availability, changing osmotic pressure in the muscle cell, and increasing catecholamine concentrations.[139] Strategies that restrict exogenous CHO availability also promote an extended signaling response, albeit less robustly than is the case for exercise with low glycogen stores.[140] These strategies enhance the cellular outcomes of endurance training, such as increased maximal mitochondrial enzyme activities and/or mitochondrial content and increased rates of lipid oxidation.

The combination of research and practical experience has led to a paradigm that athletes should train with low CHO availability (train low) to enhance the training response. Although this might be achieved chronically with an LCHF diet, strategies that could achieve it periodically around targeted training sessions include doing 2 training sessions in close succession, or minimal CHO intake in between, to enable the second bout to be done with low glycogen content (low endogenous CHO availability), or training in a fasted state with only water intake (low exogenous CHO availability). Studies of "train low" strategies in subelite athletes have reported evidence of enhanced signaling and cellular responses to training, particularly with training with low glycogen, suggesting an amplification of the training response.[141–143] However, evidence of a consistent transfer to superior performance outcomes is lacking. Issues with study methodology (eg, the difficulty of measuring performance with real-world significance; inconsistency between protocols that clamped training loads vs protocols that allowed athletes to train as hard as possible) partly explain this "disconnect" between mechanistic and performance outcomes. More importantly, however, in the early studies in which "train low" was implemented in all sessions or all of the key (high-intensity) sessions in the training program, benefits due to enhanced adaptation may have been negated by the observed reductions in quality/intensity of these sessions.[141,142] This suggests that "train low" strategies need to be carefully integrated into the periodized training program to match the specific goal of the session and the larger goals of the training phase.

A more recently identified exercise–nutrient interaction adds another strategy to the CHO periodization options. Delaying glycogen resynthesis by withholding CHO in the hours after a higher intensity training session has been shown to upregulate markers of mitochondrial biogenesis and lipid oxidation during the recovery phase[144,145] without interfering with the quality of the session. A further benefit and practical application of this protocol is that it allows the sequencing of (1) a "train high" high-quality training session, (2) overnight or within-day CHO restriction (sleep low), and (3) a moderate-intensity workout undertaken without CHO intake and, in the case of a morning session, after an overnight fast (train low). Indeed, superior training adaptation and performance outcomes have recently been reported when 3 cycles of this sequence were introduced into the weekly training programs of subelite athletes, over either a 3-week[146] or 1-week[147] period of observation. In these studies, benefits were seen with this periodized CHO approach that were not observed in another group that undertook similar training with a similar, but evenly distributed, CHO intake. These studies provide encouraging evidence that a range of "train high" and "train low" strategies could be individually integrated into the athlete's training program to amplify the desired adaptation and performance outcomes. Such an approach has been described in case studies of the preparation of elite endurance athletes.[148]

Finally, it should be recognized that studies of elite athletes appear to show less responsiveness to periodization of CHO availability than is seen in subelite athletes. An investigation of a 3-week program of intensified training in world-class race walkers failed to detect any difference in the immediate performance benefits achieved by the group who consumed a periodized CHO diet and another group who consumed the same total CHO intake, but evenly spread to promote high CHO availability for all training sessions.[149] Another study of elite endurance athletes reported no benefits to training adaptation or performance gains from the integration of a within-day sequence of a high-quality "train high"/"sleep (recover) low"/moderate-intensity "train low" protocol 3 days a week compared with a diet providing more consistent CHO availability.[150] It is uncertain whether the observed lack of additional benefits is systematically related to the caliber of the athlete: for example, a reduced ceiling for improvements in which differences are harder to detect, or an ability to undertake intensified training where the stimulus already maximizes the adaptive response[151] or depletes CHO stores even in the face of high CHO intakes around training, such that the actual differential between a diet with high or periodized CHO availability is reduced.[149] Further investigation is merited.

Spreading Nutrient Intake Over the Day to Maximize Exercise–Nutrient Interaction

In many areas of nutrition and sports nutrition, guidelines for nutrient intake are provided in terms of daily targets, with little regard for how this might be consumed over the day and in relation to exercise. In the previous theme, the deliberate organization of CHO intake around exercise sessions to either provide or withhold its availability as a fuel source was shown to achieve different outcomes to a periodized or evenly distributed spread of CHO across the day. Protein is another nutrient receiving interest around its optimal spread across the day. Protein balance is a product of muscle protein synthesis minus muscle protein breakdown, and over a day, the direction and magnitude of the balance continually alters according to factors such as intake of dietary protein, exercise, and periods without food (for review, see Phillips[152]). In the period immediately after exercise, there is a substantial increase in rates of muscle protein synthesis, especially in trained individuals.[153] This is most evident in the hours immediately after the exercise bout, and in trained subjects, it may not return to basal levels until at least 24 hours of recovery.[153] However, while exercise reduces the degree of negative protein balance that occurs between meals, the response remains negative (ie, breakdown greater than synthesis) unless the athlete consumes a source of protein[154] or, more specifically, essential amino acids.

The maximal protein synthetic response to a resistance exercise bout is achieved with the intake of ~0.3-g high-quality protein per kg of body mass (~20–25 g for the typical athlete), soon after the completion of the bout,[155] at least when this is consumed from a single and rapidly digested source. This results from the dual role of protein-rich foods in providing a source of the branched-chain amino acid, leucine, which turns on protein synthetic machinery, as well as supplying the amino acid building blocks for the construction of new proteins.[152] The optimal amount of protein, when consumed within meals and/or from more slowly digested sources, may be larger because it may require a larger amount to achieve the optimal plasma leucine concentration. Although the postexercise intake of high biological value protein has been the focus of most attention, the optimal pattern of intake to take advantage of the enhanced protein synthetic response over the rest of the day is also important. This has been shown to be a pattern of repeated meals and snacks providing the optimal protein, served every 3 to 5 hours.[156] A slightly larger protein serving, just prior to going to bed, has also been shown to enhance protein synthesis by maintaining elevated rates overnight.[157] These patterns of intake are not typically found in a Western eating style, suggesting that many athletes could improve the outcomes of their training by altering their habitual protein intake practices.

Summary

In summary, nutrition and exercise interact powerfully to promote physiological adaptations and to enhance exercise capacity. There are a number of ways in which timing the intake of nutrients over the day in relation to exercise and as part of the periodization of the athlete's training and competition calendar can enhance the outcomes of this interaction. Nutrient timing and periodization pose an exciting new area of sports nutrition in which there is an evolving evidence base, as well as the need to consider the practical aspects of consuming foods and fluids around exercise and in the athlete's busy lifestyle.

Periodization of Psychological Skills

Periodization is considered a key strategy in optimal training and sport performance, but it has not reached sport psychology in any consistent way. This section explores the possible reasons, summarizes what is presently known, and offers some suggestions for future steps.

The major stumbling block in the lack of periodized work of psychological skills in sport is the lack of agreement in the field as to what the basic sport psychology skills are. There is also some confusion between skills, tools, and outcomes. There are several labels that appear repeatedly, but that may just reflect the use of similar training methods. The second issue, assuming an agreement could be reached on the first one, would be to clarify if skills build onto each other, thus requiring some to be taught before others. There is no clear evidence for this issue, either—only some common sense or experiential evidence. Finally, there is the issue of adequately balancing psychological training intensity and volume: How many skills should be taught in 1 phase? For how long should they be practiced? What is the difficulty level of the skills? All of these are variables without evidence-based answers.

With a holistic approach to periodization, coordinating psychological skills training with physical training, recovery, nutrition, and skill acquisition, the picture becomes even more obscure (Table 1). Nevertheless, the fact that an issue is complicated or confusing is not reason enough to avoid it; on the contrary, the area should be developed and built on what has been previously learned.

Existing Models

Bacon[158] provided one of the first comprehensive descriptions of a periodized approach to mental training programs. He proposed an arbitrary combination of desired qualities for a well-prepared athlete, including being confident, optimistic, calm under pressure, mentally focused in the present, and determined.[159] Athletes should be able to improve these qualities by using psychological techniques derived from 5 basic mental skills: relaxation, positive self-talk, energization, visualization, and concentration. Inside each of these, the author listed several techniques to help train the skill.[158]

In addition to acknowledging the arbitrariness, Bacon[158] also highlighted the need for individualized training, suggested the use of a mental skills assessment tool, such as Suinn's[160] self-assessment, and recommended that athletes and coaches choose skills to work on based on the data obtained. In addition, Bacon[158] underlined the need for integrating mental training into the athlete's other training activities and making sure that the mental objectives of each phase are compatible with the objectives of the other training components. He proposed Boutcher and Rotella's[161] model, which starts with basic mental skills, then adds sport-specific mental skills, and finally individual competition strategies. Bacon[158] also addressed the sequence of skills to be taught, indicating the likelihood of needing to use some of them to effectively teach others and recommending the following sequence: relaxation, positive self-talk, energization, visualization, and concentration. Bacon also provided a detailed description of how this could be applied during a monolithic season with 1 major competition at the end. Despite being a comprehensive and practical approach, it is untested, and it only addresses the initial questions minimally, except for the recommended teaching sequence, which is also untested.

Balague[162] also proposed a model of specific skills to be trained at different phases of the training cycle, indicating that the skills addressed should match the needs of the training phase, as well as the demands of the sport and the characteristics of the athlete. The author offered a model for horizontal jumps training and proposed a modified version of Vealey's[163] classification of skills, starting with basic skills: motivation, self-awareness, productive thinking, and self-confidence. Next are performance skills: cognitive-perceptual skills, attention management, and energy management. Personal developmental skills are next: identity formation, interpersonal functioning, and media management. Finally, team functioning skills are as follows: leadership, communication skills, cohesion, and team confidence. Here, again, the model was proposed but not tested.

Hammermeister and VonGuenthner[164] also discussed the issue of periodization of psychological skills training. They proposed linking Burton et al's[165] model of mental training periodization, which emphasizes manipulating volume, intensity, and specificity, as well as rest, and matching the mental training variables to the actual phase of training. Hammermeister and VonGuenthner[164] also suggested combining the periodization model with the Mental Skills Menu,[166] which is a progressive list of exercises for various mental skills, allowing for the individualization of the program to the needs of athletes and coaches.

Holliday[167] proposed periodization as the backbone for training mental skills with the following phases: understanding, acceptance, utilization, and integration. These phases address the issue of the degree of understanding and motivation to train psychological skills, and they evoke the Stages of Change model[168] widely used in health psychology. The specific techniques to be taught are secondary to the person's willingness to accept the need for these techniques. The basic concept proposed is to become very familiar with the team's long-term training cycle, match the skills to meet the specific demands during each training phase, and systematically manipulate the volume and intensity of mental skills training (MST) during each training phase. Holliday[167] suggested that during the base training phase, foundation skills are taught; the preparatory phase incorporates MST tools; the competitive phase calls for MST skills; and the peaking phase requires mental readiness. Volume and intensity of MST are manipulated, with high volume (development of mental tools and amount of mental training) in the first 2 phases and increasing intensity (difficulty of skills, complexity, specificity, and consequences of failure) in the last 2 phases.

Holliday[167] tested this model with a pre–post measure, showing an increase in usage of MST both during practice and during competition, an increase in self-confidence, and improvements in performance (both self-rated and coach-rated). Holliday stated that individual needs took preference over planned interventions, acknowledging the importance of individualizing MST. The author also acknowledged the lack of a control group and other methodological issues but offered a comprehensive model nonetheless.

Stonecypher et al[169] described an interesting proposal, having the coaches do the mental periodization work. They suggested using the Judge and Gilreath[170] model, which simplifies skills as arousal awareness, opportunity for feedback, and motivation as focus of the preparation phases; precompetitive routines as the main preparatory skills of the precompetitive phase; and confidence as the main focus of the competitive phase. The authors described the implementation of the program with a softball pitcher. Some of the limitations of the protocol have to do with the lack of flexibility in adapting such a program to the needs of an individual athlete. For example, the study specifies the need to work back to the basics of imagery if the athlete has difficulty controlling the images. That is correct, but what to do when an athlete has very poor imagery skills overall? Although increasing the role of the coaches in periodization of psychological skills training is clearly the way forward, given the nature of the work and the complexity of psychological responses, a sport psychologist should be consistently involved with the coaches and athletes participating in the program.

Periodization of Psychological Skills in Team Sports

The information available on periodization of psychological skills in team sports is even more scant, and completely inexistent in the specific case of soccer. Perhaps the reason is that team sports present more complications from a psychological standpoint: the competitive season is long, and matches are often held weekly, which shortens the preparation phases and requires practitioners to operate in microcycles. Early competitions often function as training, although performance remains important. Table 2 displays a possible structure for the periodization of psychological skills in a team sport.

Besides the requirements shown in Table 2, periodization for team sports would also demand the consideration of the socioemotional interventions needed by the specific group development phase. Tuckman[171] proposed the most widely used model for the evolution of small groups, which he devised for work groups and has extended to athletic teams. Each phase has specific task issues and socioemotional issues and requires different responses from the team's leader (Table 3).

Ideally, Tables 1 to 3 should be combined to ensure attention to the development of psychologically relevant performance skills by the individual players, while at the same time working with the coaches to make sure they develop a cohesive, high-performing group.

Examining the above studies, several common issues emerge:

- The individual athlete's psychological needs will determine in a general way which skills he or she should work on training or acquiring. Issues such as athletic experience, level of participation, prior exposure to psychological skills training, and personal characteristics will greatly determine which skills should be addressed.
- There is a strong motivational factor to practicing mental skills, so the athletes' and coaches' choice of skills is probably helpful in that respect. That is why Balague[162] stated that identifying the psychological demands of the sport and of the current training phase, and teaching psychological skills that address these needs, would increase compliance with mental training regimes.

Table 3 Model for the Evolution of Sports Teams[171]

Phase	Task issues	Socioemotional issues	Leader behavior
Forming (goal setting)	What should we do? How are we going to do it? What are the goals?	Am I included? What is my role? Is this good for me?	Leader very active, informs, and encourages participation
Storming (clarify and promote communication)	What are the rules? Rewards and punishments? How am I evaluated?	Who has the power? Who is the boss? Who am I against?	Test limits Leader promotes expression of differences Looking for solutions
Norming (cohesiveness)	Create a sense of team Generate feedback	Sense of belonging, conflict resolution, and conformity	Group more independent of leader Promote uniformity Interaction
Performing (self-regulation)	Problem-solving Balance information action	Collaboration Compromise High productivity	Leader delegates Support expression of ideas All resources are used

- Educating the athletes regarding the different skills available is helpful; it should be done early in the athletic development process and can be done as a group activity, but training will need to be conducted, at least in part, on an individual basis.
- Some athletes may think that they do not need to build, for example, their self-confidence. This is particularly the case with gifted athletes who have been the best in their environment. Once these athletes move to a group of equally gifted individuals (ie, a professional team), or after experiencing a severe injury, for instance, self-confidence doubts may appear, and they will require tools not previously needed.
- Psychological skills, unlike physical ones, are not universally accepted in sports as essential for performance and/or trainable. Perhaps it is impossible to identify a general sequence of psychological skills for sports performance that should be followed by every athlete. The issue would then become one of assessing the type and level of skills possessed by the different athletes and showing the connection between the skills that need to be developed and the demands of the training phase for that specific sport.

Psychological Skills for Performance

What are the psychological skills most relevant to performance in the competitive periods? Most coaches and athletes would probably agree that motivation, self-confidence, effective focus, and cognitive flexibility (to allow for good decision making in the changing conditions of sport competition) would make most experts' list, followed by the ability to regulate intensity, both physically and emotionally, as well as interpersonal skills (eg, being a good teammate, being a leader).

There has been a lot of interest in the notion of "grit," identified as a group of qualities that determine probability of success given equal talent.[172] These qualities are:

- Courage: More specifically, the ability to manage fear of failure is imperative and a predictor of success. The supremely gritty are not afraid to fail, but rather embrace failure as part of a process. They understand that there are valuable lessons in defeat and that the vulnerability of perseverance is requisite for high achievement.
- Conscientiousness: The achievement-oriented individual is one who works tirelessly, tries to do a good job, and completes the task at hand. In the context of conscientiousness, grit, and success, it is important to commit to go for gold rather than just show up for practice.
- Long-term goals, endurance, and follow-through: One of the distinctions between someone who succeeds and someone who is just spending a lot of time doing something is this—practice must have purpose. That is where long-term goals come in. They provide the context and framework in which to find the meaning and value of the athlete's long-term efforts, which helps cultivate drive, sustainability, passion, courage, stamina—that is, grit.
- Resilience (optimism, confidence, and creativity): A key component of grit is resilience—the powering mechanism that draws one's head up, moves an athlete forward, and helps them persevere despite whatever obstacles they face along the way. In other words, gritty people believe "everything will be alright in the end, and if it is not alright, it is not the end."
- Excellence versus perfection: Excellence is an attitude, not an endgame. It is far more forgiving than perfection, allowing and embracing failure and vulnerability in the ongoing quest for improvement. It allows for disappointment and prioritizes progress over perfection.

The labels that Duckworth et al[172] proposed appear to be a combination of the traits listed by the coaches. Their findings—that these attributes predicted success in the performance of West Point cadets better than physical or intellectual talent—provide support for the need to find ways of training them.

One qualitative study conducted with multiple medalists or people who medaled in more than 1 sport[173] identified the following components of what the author called "performance intelligence":

- Knowing how to maximize your potential,
- Knowing how to work with your environment, and
- Knowing how to deliver high performance.

The first component combines self-awareness, confidence, and emotional regulation. The second component requires social and interpersonal awareness and cognitive flexibility. The third one includes perseverance, productive thinking, and emotional stability/regulation. Considering the population studied, Jones'[173] work provides a template for the skills to develop when looking for consistent elite performance. The major labels differ, but the components are basically the same as reported above.

Psychological Recovery

Psychological recovery is another area that has not been addressed sufficiently. In soccer and other sports with long seasons, with many matches or competitions, practitioners should find ways to help manage psychological fatigue and help with emotional recovery, as they do with physical fatigue. In general, it is known that "active rest" provides better recovery than passive activities. Engaging in a different activity that requires some cognitive skills is preferable to a passive occupation (eg, watching television).

From a longitudinal perspective, the situation of the experienced athlete, who has been in the sport for a long time and probably needs different tools to continue being motivated and continue to perform at the desired intensity, should be considered. Psychological recovery is likely to be an essential component in that specific situation. At the other end of the spectrum is the current situation of early specialization, with many youth sports having a 12-month-long season. Besides the motor learning evidence that asks for variety of motor patterns, the issue of psychological fatigue—loss of motivation—is also likely to be related to the observed pattern. These questions require further research.

Summary

Psychological skills are a central component of athletic performance. Failures are often attributed to lack of concentration, poor focus, low motivation, or mental errors. At the same time, there is no agreement as to what the basic psychological skills are and how best to train them. Periodization methods should address individual needs, include specific protocols for team sports, and address both physical and psychological recovery. In the future, obtaining evidence-based data should be the ultimate goal for researchers and practitioners alike.

Skill Periodization

Somewhat similar to the psychology literature, the skill acquisition literature is relatively bare when the concept of periodization is considered. The literature is full of experimental work that has examined 1 particular skill acquisition concept, such as the method of instruction (ie, internal vs external, simple vs complex), practice scheduling or organization (ie, blocked vs random, constant vs variable, massed vs distributed), or feedback content and timing (ie, knowledge of results vs knowledge of performance, delayed vs immediate).[174–176] However, very few researchers have attempted to pull these concepts together into a single skill development model or to tease apart the nuances of preparing team sport relative to individual sport athletes.

There are some exceptions where applied models have been proposed that provide some direction regarding skill progression.[177,178] Similarly, there are some theoretically driven models about how to optimize the practice environment for skill development and, ultimately, the attainment of expertise.[179,180] However, these models or frameworks are relatively silent on the specific issue of periodization. A recent exception was proposed by Farrow and Robertson,[181] who developed a skill acquisition periodization framework for high-performance sport that adopted the SPORT acronym previously applied in the physical training literature[182] and adapted concepts derived from the extant skill acquisition literature (note that the term "skill acquisition literature" is used liberally to describe work from the related fields of motor learning, sports expertise, and sport psychology). The following section selectively reviews these models in more detail and provides a summary of the SPORT framework for the periodization of skill (Tables 1 and 2).

One of the first groups to consider the development of skills more holistically was Vickers et al,[178] who integrated the concepts of instructional complexity, practice scheduling, and feedback delivery into a decision-training model. These authors highlighted the fallacy of a common perception in the practical setting, where coaches typically try to develop skill through a progression of simple to complex instruction coupled with significant volumes of repetitive (blocked) practice and feedback (a method Vickers et al labeled "behavioral training"). Such skill development conditions typically lead to an improvement during the practice session/s, but positive transfer to the performance setting is often poor.[183] Consequently, Vickers et al[178] pursued a more aggressive approach called "decision training," which is essentially the opposite of the behavioral training approach. That is, the instructions started with greater complexity, practice was more random/variable, and reduced levels of delayed feedback were provided. Baseball batters reflective of novice, intermediate, and advanced skill levels completed a 7-week training program in 1 of the 2 experimental conditions. Consistent with theoretical predictions, results revealed that for the 2 higher skill-level groups, the decision-training approach produced superior transfer performance (hitting percentage), despite their practice performance being suppressed, whereas the novice batters benefited from the behavioral training approach. While this is an isolated study, the findings provide some direction regarding what aspects need to be considered collectively when attempting to periodize skill.

Guadagnoli and Lee's[180] challenge point framework focused more specifically on the practice and feedback conditions required for optimal skill learning. Summarizing a large body of empirical motor learning research on the constructs of practice and feedback, these authors[180] highlighted the importance of understanding the interaction between the skill level of a performer and the relative difficulty of the skill to be practiced. A series of testable predictions was then made on the basis of these various interactions, whereby the "optimal" challenge point could be determined for a performer of a given skill level practicing a specific task. While the framework has not been subject to a great deal of empirical application as yet, the predictions of the framework are most useful in the development of a periodized model of skill development.

Perhaps the most heavily cited work in the field of skill acquisition—or, more specifically, expertise—comes from the seminal work of Ericsson et al,[179] who provided the theory of deliberate practice. Although a detailed summary of the deliberate practice research over the ensuing 20 years since its conceptualization is beyond the scope of this review (see Ford et al[184] for a review as it pertains to sport), a key point is to consider what Ericsson et al[179] would propose in relation to the periodization of skill. While periodization is not specifically mentioned, there is certainly reference to the importance placed on increasing the amount of effortful practice over time. Consequently, it was argued that selective rest and recovery is required for the learner/performer to derive the maximum benefits of deliberate practice. These recommendations fit neatly with existing periodization literature in the sport physiology domain.

Application of the SPORT Acronym

As previously suggested, the skill acquisition periodization framework[181] was motivated by some of the previous literature reviewed and then packaged using the SPORT acronym.[182] SPORT stands for Specificity, Progression, Overload, Reversibility, and Tedium. When contextualized from a skill acquisition perspective, *specificity* was defined as the extent to which practice reflected the demands typically experienced in competition. *Progression* referred to the skill performance of an individual and also considered the performer's capacity to complete and tolerate an increased skill practice load. *Overload*, or more specifically load, considered the cognitive effort demanded when practicing a skill, as well as the volume of practice accumulated. *Reversibility* focused on being able to measure the degree of skill learning that was achieved and, importantly, how permanent (or reversible) that learning was. The experience of *tedium* was considered detrimental to skill development, so practice variability was promoted as a method to reduce the likelihood of tedium appearing within a practice program.

For each element of the SPORT framework, Farrow and Robertson[181] provided a range of recommendations and hypothetical predictions about how skill could be optimally periodized in a high-performance program. An important caveat for the implementation of this approach was that routine measurement of key skill performance parameters was recorded such that practice demands could be adjusted according to an individual's or team's progression. While space prohibits a detailed review of each of these predictions, a number of key summary points can be made:

- Specificity of practice is considered an essential element of any periodized plan. While the complexity of this specificity could be systematically manipulated through variations in the constraints applied, such as the amount of defensive pressure applied or time pressure experienced, specificity is always present in some form.[185]
- Progression is contextualized in relation to the complexity of the skill to be practiced and how it interacts with the amount of practice repetitions (frequency) to be completed. In simple terms, the complexity and frequency can be manipulated (and recorded) to develop an overall load where an optimal challenge point[180] is obtained. This "optimal" load may be experienced for a number of sessions before performance is evaluated and a new challenge level developed.

- Overload is closely related to progression, and in many respects, these 2 constructs are most important in ensuring a periodized program. In skill training, consideration of the amount of cognitive effort an athlete is using to complete a task is a useful metric to consider "overload." An underpinning philosophy is that cognitive effort is usually a positive sign that the performer is being required to actively engage in skill practice.[183] From a periodization perspective, providing opportunities to unload the degree of cognitive effort is critical, particularly when considered in parallel with the physical training load (eg, see Marcora et al[186]).
- Reversibility highlights the importance of being able to systematically record skill performance to determine the degree of learning achieved. Furthermore, within a periodized program, being able to identify how long a skill can be left without practice before reversibility effects appear is particularly useful in high-performance programs that are inevitably overcrowded with competing practice needs and limited practice time.
- Tedium or the state of being bored due to monotony is argued to be detrimental to any skill development program. It is suggested that increased practice variability is a useful method for reducing the likelihood of tedium. The motor learning literature has developed an extensive body of knowledge on the value and limits of practice variability (eg, see Brady[187] for a review). Concomitantly, higher practice variability is associated with suppressed practice performance, but also with superior transfer performance and increased cognitive effort. These interactive features need to be well-understood when periodizing a skill development plan.

Summary

In summary, while there is a significant body of literature on isolated skill acquisition concepts that are important for a scientist or practitioner to understand when wishing to develop skill, they have traditionally been examined in isolation from each other. Furthermore, there has been a relative absence of research that has considered the development of skill more holistically, with some notable exceptions, as detailed in this review. The recent SPORT skill acquisition periodization framework is one such example that now requires significant empirical testing to further validate the prospects and limits of this framework as a model for skill periodization.

Conclusion

Periodization emerged several decades ago as a rational and systematic method to organize a seasonal training program into smaller periods and training cycles, usually referred to as macrocycles, mesocycles, and microcycles, with the aim of achieving a performance peak at major competitions. Since its conceptualization, periodization has become a widely used method by athletes and coaches worldwide. However, the integration of other factors that can impact athletes' readiness for optimal performance has mostly been neglected. Recent developments in various areas of the sports sciences (eg, recovery, nutrition, psychology, and skill acquisition) can contribute to the development of integrated periodization and make an impact on training theory and practice, in both individual and team sports.

Traditional or linear periodization usually divides the season into periods of general preparation, specific preparation, competition, and transition, during which training volume, intensity, specificity, and recovery are modulated in relation to the competition calendar. Alternative periodization models, such as nonlinear or undulating, block, fractal, conjugate sequence, or reverse periodization, have emerged over the years, but variations of the above training periods are a common feature. Although the quality of the research supporting periodization theory has been criticized, most sports scientists and practitioners alike understand that the essence of a periodized training program reflects a flexible and adaptive need for organizing the core components of athletic preparation and skillfully combining different training methods to optimize competition performance, rather than adhere to a rigid construct. In fact, periodized training programs have recently been shown to induce performance enhancements in a variety of individual and team sports.

Team sport athletes can indeed benefit from a periodized approach to the season, characterized by progressive overload training culminating with a 2- to 3-week taper in the preseason; in-season, the periodized training plan will depend on factors such as time between games, travel, or competitiveness of the opponents. These factors, along with fatigue and injuries, are in fact the main drivers for the recent emergence of the concept of strategic periodization (ie, the intentional peaking for matches or events of perceived greatest priority or difficulty throughout a competitive season).

Recovery strategies in general and CWI in particular can influence acute and chronic training adaptation and competition performance in individual and team sports. Withholding proactive recovery during the general preparation phase may benefit adaptation, whereas implementing recovery strategies during the specific preparation and competition periods, as well as other periods of increased recovery needs, may result in optimal performance outcomes. Similarly, a strategic or periodized manipulation of energy and nutrient intake can be used between and within training days to track changing needs or goals of training and competition and to increase the capacity for fuel utilization from carbohydrate and fat. Withholding nutritional support can increase the training stimulus or enhance training adaptation, whereas providing such support can promote optimal performance. Dietary periodization can also enhance the metabolic interaction between exercise and nutrition by arranging nutrient intake during the day.

Psychological skills and skill acquisition are central components of athletic performance, but research on the periodization of these areas is still in its infancy. Nevertheless, the available evidence suggests that psychological periodization methods should address individual needs, include specific protocols for team sports, and address both physical and psychological recovery in relation with the exercise training goals and contents. The literature on isolated skill acquisition concepts has recently evolved to provide a framework for skill periodization that can also be integrated with other components of athletic preparation.

This review has summarized the available scientific evidence underpinning the concept of integrated periodization of multiple factors that impact athlete preparation for individual and team sports performance. Specific research on integrated periodization is an emerging area of athlete preparation for competition that warrants further investigations. This review may represent a stimulus for future studies in this area.

Practical Applications

The practical applications of an integrated periodization approach for athletic preparation can easily be inferred from the discussions and summary statements made throughout this review, as well as the recommendations for individual and team sport plans presented in Tables 1 and 2, respectively. An integrated periodized approach seems to be particularly relevant in the lead-up to a major tournament, such as the upcoming 2018 FIFA (Fédération Internationale de Football Association) World Cup. Although preparing a team for a major tournament is not, in principle, radically different from preparing an individual athlete for a championship event, the complexities of a team preparation can be daunting. Although there are different approaches to optimizing team sport performance in the lead-up to the World Cup, the coaching staff should consider biological, technical, tactical, psychological, and sociological variables to decide on the most suitable strategies to get the best performance from each player. Peaking for a major international tournament usually requires choosing between recovering from domestic competition and then rebuilding players' fitness or trying to extend the fitness level of the players and capitalize on adaptations acquired during the domestic season. While both approaches can be valid, the choice should depend on the level of accumulated fatigue each player presents after the domestic competition, as well as the time available between the end of the domestic season and the beginning of the international competition. The basic structure of a period of relative rest following the regular season, followed by a block of intensive training culminating in a taper, seems to be a reasonable strategy for participating teams to adopt, but an individualized approach is often required. Training throughout the competition should aim at maintaining players' fitness and technique proficiency, achieving specific goals, and filling time. Players receiving more match time should focus on recovery throughout the tournament, whereas players receiving little or no match exposure should perform extra training to maintain their fitness and performance levels.

In the lead-up to the World Cup, teams should consider periodizing the use of individualized recovery strategies, whereby recovery is either increased or decreased to maximize performance (acute recovery) and increase adaptation (chronic recovery), respectively. Before reducing the use of recovery in a bid to increase adaptation (chronic recovery), consideration should be given to the type of training, time before the start of the tournament, phase of training, injury status, and mood state. Recovery can be used to prepare for certain training sessions (acute recovery) or can be used during the tournament to reduce fatigue (acute recovery). For example, CWI can be used to prepare for afternoon skill-based training following general fitness or weight training sessions in the morning. Cold water immersion should be completed immediately postmatch, where possible, and 3 to 4 times per week between matches (where matches are separated by approximately 1 wk). The recommended protocol for cold water immersion is 10 to 15 minutes in 10°C to 15°C water to shoulder level and in vertical position to maximize the effect of hydrostatic pressure. Other proactive recovery strategies (eg, contrast water therapy, massage, and compression garments) can also be considered in both the lead-up to and during the World Cup.

Many of the specific nutritional strategies to achieve optimal performance (eg, achieving optimal physique, using the interaction of nutrition and training to develop required physiological characteristics, development of a match nutrition plan) should have been achieved well before the World Cup period. The last 4 to 8 weeks of preparation, however, provide an opportunity to tweak any incomplete goals. The final week prior to the tournament is likely to involve a training taper with lower overall volume but with match-specific play. Each player should be guided by a sports dietitian/nutritionist to understand and address their changing needs, with a particular focus on changing needs for energy and carbohydrate intake. The pretournament nutrition plan should include thorough practice of match nutrition strategies to allow players to become habituated to valuable practices of prematch fueling and within-match fluid and fuel replacement; each player should fine-tune an individualized plan. Note that the rules of football do not allow ad libitum intake of fluid or carbohydrate within each playing period (eg, a 45-min half); therefore, players with high sweat losses and fuel use must use the prematch warm-up and half-time opportunities efficiently to consume fluids and carbohydrate sources. According to the tournament draw, teams may be required to play at different times of the day and should develop different timetables of prematch eating and postmatch recovery, according to the specific schedule of match play and travel. Additional requirements to address specific environmental conditions should be considered.

Carbohydrate intake should vary from day to day, and within a day, according to the specific fuel needs of a training session or match and the benefits of providing high carbohydrate availability (being fueled for optimal performance according to the anticipated needs of the player's position or style). While some periods or players may benefit from proactive refueling practices after key training sessions or matches (eg, early intake ~1 g/kg CHO), in other scenarios, there may be little need for this due to light training loads. In addition, optimal recovery, adaptation, and repair are achieved by a meal plan that spreads the intake of high biological value protein sources over the day (eg, soon after a match or key workouts, and at meals or snacks every 3–4 h). This strategy may need to be built into postmatch recovery practices.

With the above nutritional recommendations in mind, teams should arrange catering within the constraints of the tournament logistics, with sufficient flexibility to cater for the different nutritional needs of individual players, different likes and dislikes/intolerances, and some familiarity or cultural acceptance. Issues around food hygiene should also be built into the nutrition plan.

Learning psychological skills to be applied at the World Cup requires coaches to be intentional about it. Asking athletes periodically to reflect on their level of energy, tension/relaxation, and focus would go a long way in developing self-awareness. This should be done first in practice, both at times when performance is good and when the athlete struggles. After some training sessions and after all competitions, teams should teach evaluation by asking the 3 questions, "Good-Better-How": What was good (what did you do well)? What do you want to do better? How are you going to improve?

The warm-up is a built-in element in training and competition. In the lead-up to the World Cup, coaches should emphasize the need to include mental warm-up elements to ensure that the player is psychologically ready for training and, later on, for competition. Keeping the focus on the body, using breathing to regulate tension, having some energy generating images, and identifying training goals could be built into the existing warm-up routines and provide a foundation for self-regulation.

Designing pressure situations for players and providing skills to manage them is a great training technique for managing the pressures of competition. In addition, creating change in routine situations is also good practice—for example, allowing a very short time for warm-up or forcing a delay before a timed run or a specific skill performance. Teaching players to be flexible is essential in an environment where change is always present. Incorporating imagery in the learning and training processes can also be a valuable strategy—for example, when athletes are on the sidelines or waiting for their turn in training, have them visualize their next move. It is also important to create opportunities for social interaction in and out of the sport—for example, have players work in specific projects with team members playing in different positions or rival domestic clubs.

When preparing a team for a major tournament, such as the World Cup, bringing the team together and developing specific tactical approaches should be the priority for a coach. This would include the introduction of team rules for particular circumstances in a match. Importantly, these rules need to be specifically practiced so that they become well understood by the team. Once a team has established their own playing signature, they can be exposed to different types of opponents that they may encounter in the tournament and practice how they would deal with such approaches. Consequently, the majority of training time in this phase of preparation would consist of tactical training. A consequence of such team-focused practice is that individual touch skills are not practiced as much within a team training session. Coaches must be aware of this and must afford players regular opportunities to maintain their individual skills through high-volume "touch" sessions, where the focus is more on players feeling they are in control of their skills. Finally, note that a heavy tactical training phase can cause high mental load, so such training should be scheduled for when players are "mentally fresh" and in a state that will maximize learning time.

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