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## **Tapering for Competition: a review**

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### **Abstract**

The taper is a progressive nonlinear reduction of the training load during a variable period of time, in an attempt to reduce the physiological and psychological stress of daily training and optimize sports performance. Existing research has defined the taper, identified various forms used in contemporary sport, and examined the prescription of training volume, load, intensity, duration, and type (progressive or step). The current literature reveals that tapering strategies may be associated with a competition performance improvement of about 3% (usual range 0.5–6.0%). Particular attention given to nutrition, hydration and recovery strategies during the pre-event taper may help maximize its associated positive effects. Interactions between the taper and long-haul travel, heat, and altitude should be also taken into account with particular attention. Future progress in sports science will play an important part in refining and developing existing tapering methodologies, particularly in the context of multiple peaking for team and racket sports.

### **Résumé**

La période d'affûtage correspond à une réduction non linéaire de la charge d'entraînement lors de la période pré-compétitive, dont l'objectif est de réduire le stress physiologique et psychologique engendré par l'entraînement afin d'optimiser le niveau de performance. Les études scientifiques ont jusqu'à présent défini les différentes modalités d'affûtage, en caractérisant les pratiques adoptées par les entraîneurs et analysé l'influence des variations de volume d'entraînement, de charge de travail, d'intensité et de modalité de réduction de la charge (progressive ou par palier) sur la qualité de l'affûtage. La littérature actuelle révèle que les stratégies d'affûtage peuvent engendrer une amélioration du niveau de performance d'environ 3% (intervalle compris généralement entre 0,5 et 6,0%). Une attention accordée à la nutrition, à l'hydratation et aux stratégies de récupération durant cette période semble indispensable pour optimiser les bénéfices de l'affûtage. De même, la gestion des voyages transméridiens, l'acclimatation à la chaleur et la planification des stages en altitude semblent devoir être prises en compte avec particulièrement d'attention. Les prochaines recherches scientifiques devront aider à optimiser les stratégies existantes voire en développer de nouvelles, particulièrement dans les sports exigeant une fréquence importante de compétitions lors de la saison sportive, comme les sports collectifs et les sports de raquette.

## Introduction

The most important goal for coaches and athletes is to increase the physical, technical and psychological abilities of the athletes to the highest possible levels, and to develop a precisely controlled training program to ensure that the maximal performance is attained at the right moment of the season (*i.e.*, at each point of a major competition). In many competitive events, these top performances are often associated with a marked reduction in the training load undertaken by the athletes during the days before the competition. This period, known as the taper, has been defined by Mujika and Padilla [49] as “a progressive, nonlinear reduction of the training load during a variable amount of time that is intended to reduce physiological and psychological stress of daily training and optimize sport performance”.

In this perspective, the taper is of paramount importance to the outcome of the event. However, there is no training phase during which coaches are more insecure about the most suitable training strategies for each individual athlete, as they have most often relied almost exclusively on a trial-and-error approach. Indeed, only recently have sports scientists increased their understanding of the relationships between the reduction of the training load before a competition and the associated performance changes.

### I. Managing the training load during the taper

The training load or training stimulus in a competitive sport can be described as a combination of training intensity, volume and frequency [74]. This training load is markedly reduced during the taper in an attempt to reduce accumulated fatigue, but reduced training should not be detrimental to training-induced adaptations. An insufficient training stimulus could result in a partial loss of training-induced anatomical, physiological and performance adaptations, also known as *detraining* [48]. Therefore, athletes and their coaches must determine the extent to which the training load can be reduced at the expense of the training components while retaining or even improving adaptations. A meta-analysis conducted by Bosquet et al. [9] combined the results of tapering studies on highly trained athletes to establish the scientific bases for successfully reducing precompetition training loads to achieve peak performances at the desired point of the season. Bosquet et al. assessed the effects of altering components of the taper on performance. The dependent variable analyzed was the performance change during the taper, whereas the independent variables included reductions in training frequency, volume and intensity, taper pattern and taper duration.

#### a. Intensity

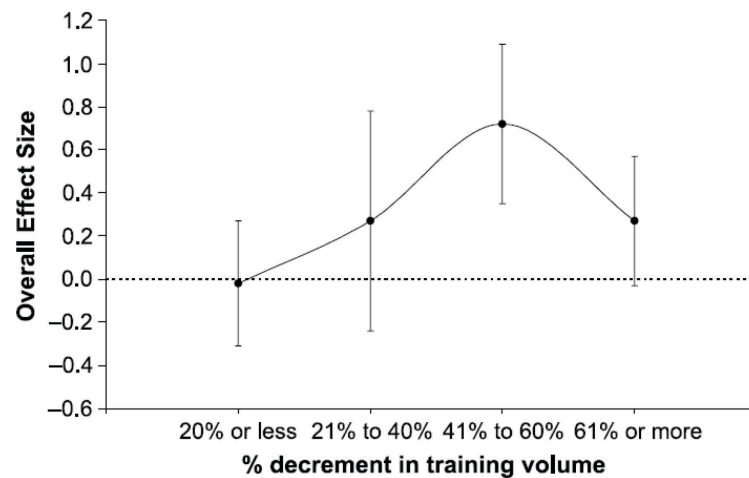
The overall effect size for taper-induced changes in performance when training intensity was reduced was -0.02 (95% confidence interval: -0.37, 0.33), in contrast with a 0.33 (0.19, 0.47) improvement when intensity was maintained or increased (Table 1). These results pointed out that the training load of athletes should not be reduced at the expense of training intensity during a taper [9].

	<i>All sports</i>		<i>Swimming</i>		<i>Cycling</i>		<i>Running</i>	
	Mean (95% CI)	<i>N</i>	Mean (95% CI)	<i>N</i>	Mean (95% CI)	<i>N</i>	Mean (95% CI)	<i>N</i>
<b>Decrease in training intensity</b>	-0.02 (-0.37, 0.33)	63	0.08 (-0.34, 0.49)	45	0.25 (-0.73, 1.24)	8	-0.72(-1.63, 0.19)	10
<b>No decrease in training intensity</b>	0.33 (0.19, 0.47)	376	0.28 (0.08, 0.47)*	204	0.68 (0.09, 1.27)†	72	0.37 (0.09, 0.66)*	100

**Table 1.** Effects of moderator variables on effect size for taper-induced changes in swimming, running, and cycling performance. \*  $p < 0.01$ ; †  $p < 0.05$ ; ‡  $p < 0.10$ . Reprinted with permission from Bosquet et al. (2007).

## b. Volume

With regard to training volume, several investigations have shown that this training component can be markedly reduced without a risk of losing training induced adaptations or hampering performance. For instance, Hickson et al. [29] reported that subjects trained in either cycling or treadmill running for 10 weeks retained most of their physiological and endurance performance adaptations during 15 subsequent weeks of reduced training, during which the volume of the sessions was diminished by as much as two-thirds. Studying highly trained middle-distance runners, both Shepley et al. [61] and Mujika et al. [47] reported better physiological and performance outcomes with low-volume than with moderate-volume tapers. Bosquet et al. [9] determined through their meta-analysis that performance improvement during the taper was highly sensitive to the reduction in training volume. These authors determined that maximal performance gains are obtained with a total reduction in training volume of 41–60% of pre-taper value, and that such a reduction should be achieved by decreasing the duration of the training sessions, rather than decreasing the frequency of training (Figure 1). This finding suggests that athletes would maximize taper-associated benefits by roughly dividing their training volume by half.



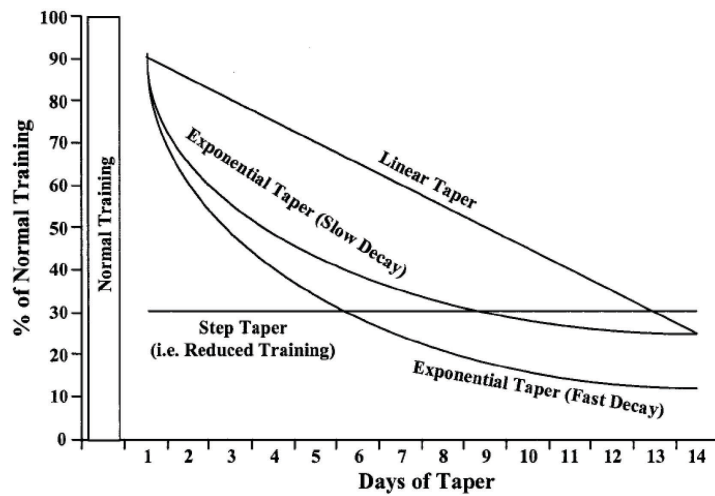
**Figure 1.** Dose-response curve for the effect of percent decrement in training volume during the taper on performance. The magnitude of the difference (effect size) was considered either small ( $<0.2$ ), moderate ( $[0.2, 0.5[$ ) or large ( $\geq 0.5$ ). Values are means and 95% confidence intervals. Adapted from Bosquet et al. [9].

### c. Frequency

According to Bosquet et al. [9], decreasing training frequency (i.e. the number of weekly training sessions) has not been shown to significantly improve performance. However, these authors pointed out that the decrease in training frequency interacts with other training variables, particularly training volume and intensity, which makes it difficult to isolate the precise effect of a reduction in training frequency on performance. While further investigations are required, this result suggested that athletes would benefit from maintaining a similar number of training sessions per week during the taper.

### d. Pattern of the taper

Mujika and Padilla [49] identify four types of taper patterns: linear taper, exponential taper with slow or fast time constant of decay of the training load, and step taper (Figure 2).



**Figure 2.** Schematic representation of the different types of taper: linear taper, exponential taper with slow or fast time constants of decay of the training load, and step taper (also referred to as *reduced training*). Adapted from Mujika and Padilla [49].

The majority of available studies used a progressive decrease of the training load. The studies of Banister et al. [8] and Bosquet et al. [9] reported bigger performance improvements after a progressive taper when compared with a step taper. Nevertheless, Bosquet et al. [9] were not able to address the effect of the kind of progressive taper (i.e., linear or exponential with fast or slow decay of the training load) on performance. Recommendations rely on the work of Banister et al. [8] with triathletes, who suggest that a fast decay, which implied a lower training volume, was more beneficial to cycling and running performance than a slow decay of the training load.

Thomas et al. [65] recently reported that the taper may be optimized by increasing the training load by 20 to 30% during the final three days of the taper, by allowing additional adaptations without compromising the removal of fatigue.

#### e. Duration of the taper

Bosquet et al. [9] found a dose–response relationship between the duration of the taper and the performance improvement. A taper duration of 8 to 14 days seems to represent the borderline between the positive influence of fatigue disappearance and the negative influence of detraining on performance. Performance improvements can also be expected after 1-, 3-, or 4-wk tapers. However, negative results may be experienced by some athletes. This interindividual variability in the optimal taper duration has already been highlighted by some mathematical modeling studies [44, 63]. Differences in the physiological and/or psychological adaptation to reduced training [44, 46, 50], as well as the use of an overload intervention in the weeks before the taper [63], are some of the variables that can account for this variability.

Recent mathematical modeling simulations suggested that the training performed in the lead-up to the taper greatly influences the optimal individual duration of the taper. A 20% increase over normal training during 28 days before the taper requires a step load reduction of around 65% during 3 weeks, instead of 2 weeks when no overload training is performed. A progressive taper requires a smaller load reduction over a longer duration than a step taper, whatever the pretaper training. The impact of the pretaper training on the duration of the optimal taper seems obvious in regard to the reduction of the accumulated fatigue. Overload training before the taper causes a greater stress and needs longer to recover. Nevertheless, the more severe training loads could make adaptations peak at higher level [64].

Millet et al. [39] used mathematical modeling to describe the relationships between training loads and anxiety and perceived fatigue as a new method for assessing the effects of training on the psychological status of athletes, in this case four professional triathletes. It was observed that the time for self-perceived fatigue to return to its baseline level was 15 days, which was close to the time modeled by previous researchers as optimal for tapering [13-14, 25]. Millet et al. (2005) concluded that a simple questionnaire to assess anxiety and perceived fatigue could be used to adjust the optimal duration of tapering.

Taken together, these results suggest that, in general, the optimal taper duration is 2 weeks, even though positive performance outcomes can occur with both shorter and longer tapers. Testing different taper durations (from 1 to 4 weeks) while using a training-log will help athletes determine their own optimal taper duration.

#### **f. Training load during the pretaper period**

Thomas and Busso [63] showed that the optimal duration of the taper for a given athlete is not constant, but depends on training done before the taper. Using a computer-simulation, these authors showed that a better performance could be achieved by increasing the training load by 20% over normal training for 28 days before the taper, but this strategy required a longer taper duration. In other words, greater training volume and/or intensity before the taper would allow bigger performance gains, but would also demand a reduction of the training load over a longer taper. This hypothesis was strengthened by Coutts et al. [21], who compared physiological, biochemical and psychological markers of overreaching in well-trained triathletes following either 4 weeks of overload training and a 2-week taper or 4 weeks of normal training and a similar taper. Overreaching was diagnosed in the intensified training group following the 4 weeks of overload training, with a worsened (-3.7%) 3-km running time-trial performance. In contrast, a gain in performance (+3.0%) was observed in the normal training group during the same period. During the taper, gains (+7.0%) in 3-km running time-trial performance were observed in the intensified training group. These findings suggested that a 2-week taper was enough for the intensified training group to recover and experience a positive training adaptation. Nevertheless, there was no difference in performance improvement between both training groups, suggesting that the length of the taper for the intensified group was not sufficient to allow for full recovery. Future work should compare different strategies for the implementation of physical training load in preparation for competition.

## II. Enhancing recovery during the taper

Achieving an appropriate balance between training stress and recovery is important in maximizing performance. The cumulative effects of training-induced fatigue must be reduced during the weeks immediately preceding competition, and a wide range of recovery modalities can be used as integral part of the taper to help optimize performance. Long-lasting fatigue experienced during the taper may be related to exercise-induced muscle injury, delayed onset muscle soreness (DOMS) [17] or an imbalance of the autonomic nervous system [27, 53]. This section discusses interventions likely to improve recovery processes.

### a. Reducing muscular fatigue

Many studies examining the efficacy of recovery modalities have focused on exercise-induced muscle damage, usually associated with DOMS, a sensation of pain or discomfort occurring 1–2 days post-exercise. Although the underlying mechanism is not well understood, full recovery of strength and power after a training session that causes DOMS may take several days [17]. Therefore, its occurrence may be detrimental to an ongoing training program. Modalities that enhance the rate of recovery from DOMS and exercise-induced muscle damage may enhance the beneficial effects of the taper for athletes.

**Massage.** Massage therapy following eccentric exercise that resulted in DOMS is a commonly used recovery treatment. Weber et al. [71] investigated massage, aerobic exercise, microcurrent stimulation or passive recovery on force recovery after eccentric exercise. There were no significant effects of any of the treatment modalities on soreness, maximal isometric contraction and peak torque production. Hilbert et al. [30] reported no effect of massage administered 2 h after a bout of eccentric exercise on peak torque produced by the hamstring muscle, however muscle soreness ratings were decreased 48 h post-exercise. Farr et al. [22] also reported no effect of 30 min leg massage on muscle strength in healthy males, although soreness and tenderness ratings were lower 48 h post-exercise. However, a significant improvement in vertical jump performance was reported after a high intensity exercise in college female athletes [38].

As can be observed from the above information, there are very few investigations which have examined the effect of massage on sports performance. There is also a wide range of massage techniques utilized and outcome measures examined. However, there may be some evidence to suggest that massage after eccentric exercise may reduce muscle soreness [72]. Moraska [42] showed that the training level of the therapist impacts effectiveness of massage after a 10-km race. Many studies investigating massage and its relevance to recovery have examined the mechanisms of massage and thus there is slightly more research in this area when compared to that of performance. Interestingly, a recent research [34] reported that a combined treatment of 30 min manual massage and 12 h lower limb compression (*i.e.* wearing compressive clothing) significantly moderated perceived soreness at 48 and 72 hours after plyometric exercise in comparison with passive recovery or compression alone.

**Compression garments.** The use of clothing with specific compressive qualities is becoming increasingly widespread, especially as competition approaches, and studies have shown improved performance and recovery after exercise-induced damage [2, 35, 66]. The use of lower limb compression for athletes derives from research in clinical settings showing positive effects of



compression following trauma or some chronic diseases. Bringard et al. [10] observed positive effects of calf compression on calf muscle oxygenation and venous pooling in resting positions, whilst Hirai et al. [31] reported reduced foot oedema in patients with varicose veins. These effects can be attributed to the alteration in hemodynamics resulting from the application of compression [32]. Studies investigating whether these effects are transferable to athletic populations found some encouraging results [2, 11], but other research did not [26, 66]. The positive effect reported by some studies may be associated with the ability of compression to moderate the formation of oedema associated with exercise-induced muscle damage and to expedite the removal of cellular debris by affecting local hemodynamics. Compression has also been suggested to offer mechanical support to the muscle, allowing faster recovery after damaging exercise [35]. Kraemer et al. [35] speculated that a 'dynamic casting' effect caused by compression may promote stable alignment of muscle fibers and attenuate the inflammatory response. This would, therefore, reduce both the magnitude of muscle damage and recovery time following injury. Although further research is required to test these hypotheses, athletes could be encouraged to use lower limb compression during the taper, notably when they are engaged in long-haul travel.

#### **b. Rebound of the autonomic nervous system activity**

Athletes usually endure very severe training loads, which induce both adaptive effects and stress reactions. The high frequency of the stimuli imposed ensures that these adaptive effects are cumulative. Unfortunately, incomplete recovery from frequent training can make the stress-related side-effects cumulative as well. One key aspect of the stress response is the decrease of the activity of the autonomic nervous system (ANS), which functions to regulate the basic visceral (organ) processes needed for the maintenance of normal bodily functions. Garet et al. [27] reported that the reduction of the ANS activity during intensive training was correlated with the loss in performance of seven well-trained swimmers, and the rebound in ANS activity during tapering paralleled the gain in performance. In this perspective, one of the main goals of recovery during the taper would be to increase the magnitude of the ANS reactivation [27]. Several recovery methods enhance the autonomic tone, including nutritional strategies (promoting low glycaemic index carbohydrates, fruits and vegetables), massage [72] and whole-body or face cold-water immersion [1, 12]. Nevertheless, the most important factor determining the ANS reactivation seems to be sleep duration and quality. Maximizing sleep in a dark, calm, relaxing and fresh atmosphere is essential during the week preceding the race for optimal performance [28]. A warm shower may help to initiate sleep. Naps may also be planned by the athlete at the beginning of the afternoon but should not last more than 20 to 30 minutes to avoid the maintenance of a lethargic state during the remainder of the day [55].

### **III. Managing nutrition and hydration during the taper**

Maintaining a good nutritional and hydration status remains critical for successful participation in competition. Starting a race with a poor hydration status or low glycogen stores directly endanger the performance level of the athlete engaged in endurance competitive events. Both nutrition and hydration strategies need to be adopted during the precompetition period to maximize the taper-associated benefits.

#### **a. Ensuring a good hydration status**

Environmental heat stress can challenge the limits of an athlete's cardiovascular and temperature regulation systems, body fluid balance, and performance. Evaporative sweating is the principal means of heat loss in warm-hot environments where sweat losses frequently exceed fluid intakes. When dehydration exceeds 3% of total body water (2% of body mass) then aerobic performance may be consistently impaired independent and additive to heat stress. Dehydration augments hyperthermia and plasma volume reductions, which combine to accentuate cardiovascular strain and reduce  $\dot{V}O_{2\max}$  [18]. Casa et al. [16] showed recently that a small decrement in hydration status (body mass loss of 2.3%) at the start of a 12-km race impaired physiologic function and performance while running in the heat. This finding highlighted that the maintenance of adequate hydration during the taper and especially during the 48 h preceding the competition is crucial for ensuring that work capacity is not diminished at the beginning of the race.

Urine color is an inexpensive and reliable indicator of hydration status [6]. Normal urine color is described as light yellow, whereas severe dehydration is associated with a brownish-green color. Although urine color tends to underestimate the level of hydration and it may be misleading if a large amount of fluid is consumed rapidly, it may provide a valid means for athletes to self-assess hydration level, notably during the taper period.

#### **b. Favoring the glycogen resynthesis/supercompensation**

Energy metabolism can be altered during a taper. Reductions in the training-load in favor of rest and recovery lower an athlete's daily energy expenditure potentially impacting on their energy balance and body composition. Athletes should therefore pay special attention to their energy intake during the taper to avoid energy imbalance and undesirable changes in body composition. Some studies indicate that training-load alterations are not necessarily accompanied by matched changes in dietary habits, and this has a direct impact on athletes' body composition [3, 45]. It is therefore advisable for athletes to take into account training schedules and loads, which can vary dramatically between peak-training and the taper. In this context, athletes need to be educated to match their energy and macronutrient intake to their training load.

Wilson and Wilson [75] suggested not only to match energy intake to energy expenditure, but also to insist on carbohydrate-loading during this precompetition period to optimize muscle glycogen storage (carbohydrate intakes of 10–12 g.kg<sup>-1</sup>.d<sup>-1</sup> over the 36–48 h prior to a race). Walker et al. [67] reported that cyclists increased their performance during a time-to-fatigue exercise performed at 80%  $\dot{V}O_{2\max}$  in response to a high-carbohydrate diet (~78% carbohydrate) compared with a moderate-carbohydrate diet (~48% carbohydrate) followed during the last 4 days of the taper. Interestingly, Sherman et al. [62] showed that no glycogen-depleting period of exercise is needed to induce such supercompensation phenomenon in well-trained runners undergoing 3 days of high carbohydrate intake during the taper. If a two-phase taper is planned (increase of the training load during the final days prior to competition), this strategy may be particularly beneficial [45].

#### **IV. Particular aspects**

A taper targets the removal or minimization of an athlete's habitual stressors, permitting physiological systems to replenish their capabilities or even undergo "supercompensation". There is very little scientific information regarding the possible interactions of environmental variables on tapering processes in athletes, whether the stressor is heat, cold or altitude. Experimental work on the additive effects of altitude on climatic stress and travel fatigue or jet-lag is lacking [54]. This gap in knowledge is largely due to the enormous difficulties in addressing these problems adequately in experimental designs, and the challenges that researchers in the field are faced with in controlling the many variables involved. Nevertheless, the likely effects of environmental factors must be considered in a systematic way when tapering is prescribed within the athlete's annual plan.

##### **a. The stress of travel**

International travel is an essential part of the life of elite athletes both for competition and training. Long-distance travel is associated with a group of transient negative effects, collectively referred as 'travel fatigue', which result from anxiety about the journey, the change to an individual's daily routine, and dehydration due to time spent in the dry air of the aircraft cabin. Travel fatigue lasts for only a day or so, but for those who fly across several time zones, there are also the longer-lasting difficulties associated with 'jet lag'. The problems of jet lag can last for over a week if the flight crosses 10 time zones or more and they can reduce performance. Knowledge of the properties of the body clock enables the cause of the difficulties to be understood (an unadjusted body clock), and forms the basis of using light in the new time zone to promote adjustment of the body clock [70].

The time-scale for adjustment of the body clock can be incorporated into the taper when competition requires travel across multiple meridians. It is logical that sufficient time is allowed for the athlete to adjust completely to the new time zone before competing [70]. The period of readjustment might constitute a part of the lowered training volume integral to the taper. Allowance should be made for the timing of training over the first few days, since training in the morning is not advocated after travelling eastwards so that a phase delay rather than the desired phase advance is not erroneously promoted [59]. There also seems little point in training hard at home prior to embarkation, since arriving tired at the airport of departure may slow up adjustment later [69]. Similarly, attempting to shift the phase of the body clock in the required direction for some days prior to departure is counterproductive, since performance (and hence training quality) may be disrupted by this strategy [56].

Tapering should proceed as planned in the company of jet-lag even if the interactions between body clock disturbances and the recovery processes associated with tapering have not been fully delineated. While quality of sleep is an essential component of recovery processes, napping at an inappropriate time of day when adjusting to a new time zone may slow up re-synchronization [41], but in certain circumstances a short nap of about 30 min can be restorative [68]. Suppression of immune responses is more likely to be linked with sleep disruption than with jet-lag per se [57]. The circadian rhythm in digestion is largely exogenous and jet-lag is associated mainly with a displacement of appetite rather than reduced energy intake [58]. Therefore, readjustment of the body clock should be harmonized with the moderations of training during the taper. Athletes, coaches and support staff should implement strategies to minimize the effects of travel stress prior to departure, during long-haul international travel, and upon arrival at the destination.

## **b. Heat acclimatization**

Many competitions take place during summer and in warm environmental conditions, and exercising in the heat can lead to serious performance decrements. Because heat acclimatization seems to be the most effective strategy to limit the deleterious effect of heat on performance, this specific aspect needs to be taken into account by athletes to optimize the benefits of the taper. Tapering in hot conditions before competition is compatible with the 7-14 days reduction in training volume advocated when encountering heat stress. The increased glycogen utilization associated with exercise in the heat should be compensated by the reduced training load – both intensity and duration [4]. Athletes should be acclimatized to the heat, otherwise performance in the forthcoming competition might be compromised.

Regular exposure to hot environments results in a number of physiological adaptations that reduce the negative effects associated with exercise in the heat. These adaptations include a decreased body core temperature at rest, decreased heart rate during exercise, increased sweat rate and sweat sensitivity, decreased sodium losses in sweat and urine, and an expanded plasma volume [5]. The effect of acclimatization on plasma volume is extremely important in terms of cardiovascular stability as it allows for a greater stroke volume and a lowering of the heart rate [51].

The process of acclimatization to exercise in the heat begins within a few days, and full adaptation takes 1-2 weeks for most individuals [73]. Recently, Lorenzo et al. [37] reported by trained cyclists that heat acclimation ( $\sim 50\%$   $\dot{V}O_{2\max}$  in  $40^{\circ}\text{C}$ ) increased  $\dot{V}O_{2\max}$ , time-trial performance and power output at lactate threshold by 8%, 8% and 5% in hot conditions ( $38^{\circ}\text{C}$ , 30% of relative humidity), respectively. In the same time, heat acclimation increased plasma volume ( $6.5 \pm 1.5\%$ ) and maximal cardiac output in cool and hot conditions ( $9.1 \pm 3.4\%$  and  $4.5 \pm 4.6\%$ , respectively). A control group had no changes in  $\dot{V}O_{2\max}$ , time-trial performance, lactate threshold, or any physiological parameters. Besides, it is clear that the systems of the human body adapt at varying rates to successive days of heat exposure. The early adaptations during heat acclimatization primarily include an improved control of cardiovascular function through an expansion of plasma volume and a reduction in heart rate. An increase in sweat rate and cutaneous vasodilation is seen during the later stages of heat acclimatization [5]. Well-trained athletes exhibit many of the characteristics of heat-acclimatized individuals and are therefore thought to be partially adapted; however, full adaptation is not seen until at least a week is spent training in the heat [51]. It is not necessary to train every day in the heat, as exercising in the heat every third day for 30 days results in the same degree of acclimatization as exercising every day for 10 days [23]. Because maintenance of an elevated body core temperature and stimulation of sweating appear to be the critical stimuli for optimal heat acclimatization, strenuous interval training or continuous exercise should be performed at an intensity exceeding 50% of the maximal oxygen uptake [5]. There is evidence that exercise bouts of about 100 minutes are most effective for the induction of heat acclimatization and that there is no advantage in spending longer periods exercising in the heat [36].

Unfortunately, heat acclimatization is a transient process and will gradually disappear if not maintained by repeated exercise-heat exposure. It appears that the first physiological adaptations to occur during heat acclimatization are also the first to be lost [5]. There is considerable variability in the results of studies concerning the rate of decay of heat acclimatization, as some authors report significant losses of heat acclimatization in less than a week, whereas others show that acclimatization

responses are fairly well maintained for up to a month. In general, most studies show that dry-heat acclimatization is better retained than humid-heat acclimatization and that high levels of aerobic fitness are also associated with a greater retention of heat acclimatization [51].

### c. Altitude

At altitude,  $\dot{V}O_{2\max}$  is reduced according to the prevailing ambient pressure. An immediate consequence is that the exercise intensity or power output at a given relative aerobic loading is decreased. In the first few days at altitude, a respiratory alkalosis occurs due to the increased ventilatory response to hypoxic conditions. This condition is normally self-limiting due to a gradual renal compensation. Athletes using training camps at altitude resorts recognize that a reduction in training load is imperative at altitude, prior to an increase as the initial phase of acclimatization occurs. The extra hydration requirements due to the dry ambient air and the initial diuresis, combined with plasma volume changes [60], increased utilization of carbohydrate as substrate for exercise [15], and propensity to sleep apnoea [52], run counter to the benefits of tapering. In this instance, the reduced training load would not substitute for a taper. There is the added risk of illness due to decreased immunoreactivity associated with exposure to altitude [60]. Maximal cardiac output may also be reduced in the course of a typical 14- to 21-day sojourn at altitude as a result of the impairment in training quality. Altitude training camps should therefore be lodged strategically in the annual plan to avoid unwanted, if unknown, interactions with environmental variables.

Altitude training is used in many sports at elite level for conditioning purposes. For example, it is accepted as good practice among elite swimmers and rowing squads preparing for Olympic competition despite an absence of compelling evidence of its effectiveness. There remains a question as to the timing of the return to sea level for best effects, an issue relatively neglected by researchers in the field, with a few exceptions [33]. Three phases have been observed by coaches [40]. So far, however, these are not fully supported by scientific evidence and are therefore under debate:

- (i) A positive phase observed *during the first 2–4 days*, but not in all athletes.
- (ii) A phase of progressive reestablishment of sea level training volume and intensity. The probability of good performance is reduced. This decrease in performance fitness might be related to the altered energy cost and loss of the neuromuscular adaptations induced by training at altitude.
- (iii) *15–21 days after return to sea level*, a third phase is characterized by a plateau in fitness. The optimal delay for competition is during this third phase, although some athletes may reach their peak performance during the first phase. Improvement in energy cost and loss of the neuromuscular adaptations after several days at sea level, in conjunction with the further increase in  $O_2$  transport and delayed hypoxic ventilatory responses benefits, may explain this third phase.

In this context, a period of lowered training is observed prior to competing after altitude training, which constitutes a form of tapering. The extent of the benefit, as well as the variation between individuals, has not been adequately explored. Future investigations are required.

#### **d. Multiple peaking during the competitive season**

Most experimental and observation research on tapering in the scientific literature has been conducted in the context of singular sport events [54]. In contrast, many sports offer reduced opportunities to taper because of the repetition of the competitions during the season. Peaking for major competitions each month (even every other week) usually poses the problem of choosing between recovering from previous competition and then rebuilding the athlete's fitness, or maintaining intensive training and capitalizing on adaptations acquired during the previous training cycle. Both approaches can be valid, and the choice should depend on the level of fatigue present after a race (or a series of competitions) and the time frame between the last competition and the next one. Additional research is required to examine the taper in the context of multiple peaking. Nevertheless, some guidelines could be addressed.

- Optimized taper periods associated with large training volume reduction (~50%) over a prolonged period (~2 weeks) should be scheduled 2 to 3 times per year. Additional taper periods may be detrimental for performance improvement by minimizing the total time of normal/heavy training load, which is essential to induce training adaptations.
- Prioritizing a limited number of races each season (e.g. 2-3 major events) seems to be a good solution to plan the taper periods in the competitive season. Altitude camps may be adequately programmed before these competitions.
- A sufficient training block lasting at least 2 months should be planned between two major objectives to allow for appropriate recovery, training and taper phases.
- Only short duration tapers (~4-7 days) should be programmed before minor events, paying special attention to recovery (nutrition, hydration, sleep, massage, hydrotherapy, compression garments). Because of the likely persistence of training-induced fatigue despite such short tapers, athletes should be aware that this strategy may sometimes lead to below optimal performances.
- Because the recovery period consecutive to minor competitions (associated with non-optimal taper) should be as short as possible to allow a quick restoration of the training load, long-haul travel should be avoided.

#### **e. Tapering in team sports**

Appropriate planning of training intensity is extremely important for team sport athletes because they usually need to perform at a high level every week for several months. In team sports, however, it is not always possible to include a taper phase in the annual training program. Nevertheless, a training taper at the end of the pre-season could help a team peak and complete a league format competitive season in the best possible condition. Moreover, a taper could also be a suitable strategy for a team to optimally prepare for major international tournaments [43].

A periodized conditioning program in the pre-season to optimize team players' physical capacities at the onset of the competitive season should follow the same strategies recommended for individual

sport athletes. Coutts et al. [20] examined the influence of deliberate pre-season overreaching and tapering on muscle strength, power, endurance and selected biochemical responses in semi-professional rugby league players. The athletes completed 6 weeks of progressive overload training with limited recovery periods, followed by a 7-day progressive taper, during which training time was reduced by 55% and training intensity by 17%. Following the overload period, multistage fitness test running performance was reduced by 12.3%, and most other strength, power and speed performance measures tended to decrease (range 13.8% to 3.7%). Changes were also observed in selected biochemical markers such as plasma testosterone to cortisol ratio, creatine kinase, glutamate and glutamine to glutamate ratio. After the taper, an increase in peak hamstring torque and isokinetic work was observed, as well as increases in the multistage fitness test, vertical jump, 3- RM squat, 3-RM bench press, chin-up and 10m sprint performance. All biochemical markers tended to return to baseline values. After inducing a state of overreaching, a subsequent progressive taper may facilitate supercompensation in muscular strength, power and endurance, likely due to increased anabolism and reduced muscle damage [19]. Repeated-sprint ability, which is a basic performance requirement for most team sports, can also be enhanced through periodized training and tapering. Bishop and Edge (2005) investigated the effects of a 10-day taper subsequent to 6 weeks of intense training on repeated-sprint performance in recreational level team-sport female athletes. Subjects were tested for repeated-sprint ability (5-6 s all-out cycling sprints every 30 s) before and after the tapering period. The 10-day taper resulted in increased total work (4.4%;  $P = 0.16$ ) and peak power (3.2%;  $P = 0.18$ ), and a reduced work decrement ( $10.2 \pm 3.5\%$  vs  $7.9 \pm 4.3\%$ ;  $P < 0.05$ ). It appears that tapering from high-intensity training is a strategy for promoting improved repeated-sprint ability in team sports, and subjects could attain performance gains if they maintain or increase training intensity during the taper.

Bangsbo et al. [7] described the preparation program of the Danish National football team for the 2004 European Championship. At the end of the club season, the players rested for 1–2 weeks before preparing for the championship. The preparation lasted 18 days divided in two 9-day phases. The amount of high-intensity exercise was similar in both phases (i.e. training intensity was maintained), while the total amount of training was reduced in the second phase (i.e. training volume was tapered). Anecdotaly, the team qualified for the quarterfinals of the tournament, beating Italy and Bulgaria along the way. Given large individual differences among players in the amount of high-intensity work performed during the tactical components of the training sessions, a careful evaluation of individual physical training load is essential, even during training time not specifically dedicated to fitness development. Ferret and Cotte [24] reported on the preparation of the French National football team in the lead-up to the World Cups of 1998 and 2002. In 1998, the team focused on developing the athletic qualities of the players through two training phases followed by a 2-week tapering phase. The taper was characterized by high-intensity training situations (friendly games) and a moderate training volume that allowed the elimination of the negative effects of training (fatigue) while maintaining the adaptations previously achieved. Following this training and peaking plan was a World Cup victory. Four years later, an almost identical group of players was eliminated after a qualifying round without a single victory or goal scored. All players were only available to the national team 8 days before the beginning of competition, and medical and biochemical markers indicated that most players were too severely fatigued for the technical staff to implement a development training phase followed by a taper to peak the physical qualities of the players.

The importance of training intensity established in individual athletes also applies in the case of team athletes. The relevant research studies indicate that a pre-tournament taper should be characterized by low-training volume and high-intensity activities.

## Conclusion

The taper is a key element of the physical preparation of athletes in the weeks before a competition. Since the early 1990s, there has been substantial research interest in the taper and its importance in the transition of athletes from the preparatory to competitive phase of the season. Physiological and performance adaptations can be optimized during periods of taper preceding competitions by means of significant reduction in training volume, moderate reduction in training frequency and maintenance of training intensity. Particular attention given to nutrition, hydration and recovery strategies during the pre-event taper may help maximize its associated positive effects. In this context, tapering strategies may be associated with a competition performance improvement of about 3% (usual range 0.5–6.0%).

Future progress in sports science will play an important part in refining and developing existing tapering methodologies. These developments should involve a combination of research and practical experience of coaches and athletes, experimental and observational research, and elegant mathematical models to refine our understanding of the physiological and performance elements of the taper.

*Les auteurs déclarent ne pas avoir de conflit d'intérêt par rapport au présent article.*

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