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Review

Intense training: the key to optimal performance before and during the taper

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The training load is markedly reduced during the taper so that athletes recover from intense training and feel energized before major events. Load reduction can be achieved by reducing the intensity, volume and/or frequency of training, but with reduced training load there may be a risk of detraining. Training at high intensities before the taper plays a key role in inducing maximal physiological and performance adaptations in both moderately trained subjects and highly trained athletes. High-intensity training can also maintain or further enhance training-induced adaptations while athletes reduce their training before a major competition. On the other hand, training volume can be markedly reduced without a negative impact on athletes' performance. Therefore, the training load should not be reduced at the expense of intensity during the taper. Intense exercise is often a performance-determining factor during match play in team sports, and high-intensity training can also elicit major fitness gains in team sport athletes. A tapering and peaking program before the start of a league format championship or a major tournament should be characterized by high-intensity activities.

A taper is the training phase characterized by a reduction of the amount of training that athletes undergo during the final days leading to a major competition. The aim of the taper is to diminish fatigue induced by intense training, maximize physiological adaptations and consequently performance (Bosquet et al., 2007). The reduction of the training load can be achieved by various modifications of an athlete's training program, such as reducing training frequency (diminishing the number of sessions), reducing training volume (shortening the duration of sessions) and/or reducing training intensity (making the training bouts less demanding for a given duration). An excessive reduction in training load (the total training stimulus imposed on an athlete, usually quantified as a combination of training volume weighted by training intensity), however, could be detrimental to training-induced adaptations, and elicit a partial or complete loss of training-induced anatomical, physiological and performance adaptations, i.e. detraining (Mujika & Padilla, 2000). To avoid detraining, it is important to determine the extent to which the training load can be reduced, while retaining or improving adaptations and athletic performance.

Training before the taper phase can have a major impact on an athlete's fatigue and adaptation levels. Intense training in particular is a type of training that not only induces high levels of fatigue but also can maximize adaptations. In the following sections, the impact of training intensity on the physiological and performance adaptations to training and tapering are reviewed briefly. Given different physiological demands, training design, competition calendar and performance assessment criteria, the taper for individual and team sports is analyzed separately, although many of the conclusions that can be extracted from individual sport research have direct implications for team sports athletes.

Intense training in individual sports

Several studies analyze the effects of intensity, duration and frequency of exercise as determinants of the cardiovascular response of healthy but previously untrained individuals to a training program (Shephard, 1968; Faria, 1970; Davies & Knibbs, 1971). These studies highlight that intensity of the effort relative to the individual's initial fitness level is a major factor influencing the magnitude of training-induced adaptations in fitness and exercise performance. Similarly, in a study of the interactions of exercise training intensity, frequency and duration in altering maximal oxygen consumption (VO_{2max}), Wenger and Bell (1986) concluded that intensity is the key factor in producing improvements in aerobic capacity.

The importance of training intensity also applies to athletic populations. Rusko (1987) evaluated the longitudinal changes in the aerobic power characteristics of cross country skiers, and concluded that intense training at and above the intensity corresponding to the so-called "anaerobic threshold" is most effective in inducing improvements in VO_{2max}. Mujika et al. (1995) reached a similar conclusion after studying the relationships between the mean intensity of a training season, training volume and frequency and the changes in performance in a group of 18 elite level swimmers. The improvement in performance during the follow-up training season was correlated with the mean intensity of the season ($r = 0.69$), but not with training volume or frequency.

Various researchers have also emphasized the effectiveness of high-intensity interval training as a means to enhance physiological adaptations and performance capabilities of already highly trained endurance athletes. Acevedo and Goldfarb (1989) reported that high-intensity training and "Fartlek" workouts by highly trained long-distance runners at 90–95% of the maximal heart rate (HR_{max}), 3 days per week for 8 weeks resulted in a 3% improvement in 10 km run time and a 20% gain in a treadmill run to exhaustion at 14.5–18.5 km/h, despite trivial changes in VO_{2max} and ventilatory threshold. This improvement was attributed to a lowered lactate concentration at the intensity at which the athletes had trained, and to subjects being able to exercise at a higher percent of their VO_{2max} before reaching the onset of blood lactate accumulation. Lindsay et al. (1996) evaluated the effects of a 4-week program of high-intensity training in competitive cyclists. The training consisted of replacing 15% of the usual prolonged moderate intensity base training with two to three weekly sessions of six to eight repetitions of 5 min at 80% of their peak aerobic power interspersed with 60 s recovery periods. The program elicited 3.5%, 4.3% and 19.8% gains in a 40 km cycling time trial performance, peak aerobic power and a timed ride to exhaustion at 150% of peak aerobic power, respectively. Similarly, Stepto et al. (1999) reported substantial performance enhancements in a 40 km time trial in highly trained cyclists after completion of six high-intensity training sessions over 3 weeks, consisting of either eight times 4 min at 85% of peak aerobic power (3.3% gain) or 12 times 30 s at 175% of peak aerobic power (1.9% gain).

In a study on highly trained middle and long-distance runners, Denadai et al. (2006) reported improvements in velocity associated with VO_{2max} (1.2–4.2%), running economy (2.6–6.3%) and 1500 m performance (0.8–1.9%) after eight high-intensity training sessions characterized by five repetitions lasting 60% of the time limit at the peak aerobic velocity. A 4-week high-intensity training intervention in well-trained rowers involving 8 by 2.5-min intervals at 90% peak aerobic velocity also produced gains of 1.9% in 2000 m time, 5.8% in 2000 m rowing power and 7.0% in relative VO_{2peak} (Driller et al., 2009). Endurance-trained runners drastically reduced their training volume from 45 km per week to 10 km for 4 weeks, but supplementing training with eight to 12 sprint runs lasting 30 s three to four times per week reported significant performance gains during intense exercise. Improvements were related with an increased muscle sodium–potassium pump expression and a tighter control of potassium homeostasis (Iaia et al., 2008). These researchers also observed 6–8% lower VO_2 at submaximal running speeds, while muscle oxidative capacity, capillarization and 10 km running performance were maintained (Iaia et al., 2009).

Thus, training intensity is of paramount importance to maximize training adaptations in both untrained subjects and highly trained athletes. There is evidence for the use of high-intensity training as a strategy to maximize physiological and performance adaptations of well-trained athletes in a variety of individual sports and modes of locomotion.

Intense training during tapering in individual sports

Hickson et al. (1985) provided the first insight into the key role of training intensity on aerobic power and endurance during periods of reduced training. Following a 10-week cycling and running training program of 40 min per day, 6 days per week, the work intensity of their moderately active subjects was reduced by 33% or 66% for 15 weeks, while maintaining training volume and frequency. The 33% intensity reduction group showed close to 9% reductions in VO_{2max} after 10 weeks, but values remained above pre-training levels. Five-minute exercise performance (short-term endurance) was maintained over the 15 weeks in this group, while the cycling time to exhaustion at 80% of VO_{2max} (long-term endurance) decreased by 21%. VO_{2max} was reduced by the fifth week of reduced training in the 66% intensity reduction group, and treadmill VO_{2max} was not higher than pre-training after 15 weeks of reduced training. Moreover, short-term cycling endurance decreased by the fifth week of reduced training, and long-term endurance declined by 30 % after 15 weeks. These data support that training intensity is essential for maintaining the training-induced increased aerobic power during periods of reduced training.

Another key investigation that highlighted the role of training intensity on athlete's adaptation to the taper was performed by Shepley et al. (1992). These authors investigated some of the physiological and performance effects of three different 7-day tapers in highly trained middle-distance runners. The different tapers included a concomitant reduction in training intensity and volume, maintenance of training intensity with a sharp reduction in training volume and a rest-only procedure. The low-intensity taper consisted of continuous running at 57–60% of VO_{2max} during each of the days of the taper. In contrast, the high-intensity taper was characterized by a standard warm-up followed by a series of intense 500 m intervals at 115–120% of VO_{2max} interspersed by a recovery walk lasting 6–7 min. Time to fatigue during treadmill running at a pace equivalent to individual best 1500 m time improved only with the high-intensity taper (22% improvement). Maximal voluntary isometric strength of the knee extensors increased to a similar extent after all three procedures (10–19%). The high-intensity taper also induced a 15% increase in muscle glycogen concentration, an 18% increase in citrate synthase activity and 5–15% increase in total blood and red cell volume. The highly trained middle-distance runners improved their performance during a high-intensity exhaustive treadmill run by sharply reducing training volume while maintaining or slightly increasing training intensity. Improvements were mainly attributed to an increased oxidative enzyme activity and/or increases in blood and red cell volume (Shepley et al., 1992).

Houmard et al. (1994) designed a study in which 18 male and six female distance runners were assigned to a 7-day run taper during which total weekly training volume was reduced to 15% of the previous training volume, a cycling taper of the same volume and duration, or a control group that continued with normal training. The run taper mainly consisted of intense 400 m intervals at 5 km race pace or somewhat faster, whereas the cycling taper consisted of similar intervals in terms of repetition number, duration and intensity, to ensure an equivalent training stimulus between groups. Relative exercise intensity may have been slightly higher in the cycling taper group given that VO_{2max} and HR_{max} are typically lower during cycling compared with the running exercise. Only the run taper group improved 5 km performance by a mean of 2.8%. In addition, this group reduced their relative and absolute oxygen consumption during a submaximal run by 5% and 6%, respectively, indicating an improvement in running economy. The fractional utilization of VO_{2peak}, expressed in both absolute and body mass relative terms, also decreased by 6%. Increases in maximal speed (2%) and time to exhaustion (4%) during an incremental treadmill test to volitional fatigue were significant in the run taper group, but not in the cycling taper or in the control group. It appears that an improvement in running economy as a function of the reduction in training coupled with a high-intensity sport-specific exercise can enhance performance.

Middle-distance runners were the participants in a study in which the physiological and performance responses to a 6-day taper were evaluated (Mujika et al., 2000). Both low-intensity continuous training (at heart rate below maximal blood lactate steady state) and high-intensity interval training (interval sets at running speeds above the speed corresponding to maximal blood lactate steady state) were progressively reduced to either 50% or 25% of pre-taper values. None of the taper protocols resulted in improvements in an 800 m competition run, but the high-intensity interval training performed during the taper correlated with changes in circulating total testosterone concentration, whereas a high volume of low-intensity continuous running was associated with higher plasma creatine kinase levels and lowered total testosterone. Therefore, high-intensity training during the taper may promote anabolic processes that facilitate recovery.

Bosquet et al. (2007) performed a meta-analysis to quantify the performance effects of altering components of the taper in competitive athletes. Out of 182 potential studies, 27 met the criteria established by the authors for inclusion in their meta-analysis: participants had to be competitive athletes, sufficient detail regarding the procedures used to decrease the training load was required, performance had to be assessed either in competition or using field-based tests and all necessary data to calculate effect sizes had to be reported. The dependent variable analyzed was the performance change during the taper, whereas the independent variables included reductions in training frequency, volume and intensity. The overall effect size for taper-induced changes in performance when training intensity was reduced was -0.02 (95% CI -0.37, 0.33), in contrast with a 0.33 (0.19, 0.47) improvement when intensity was maintained or increased. In a separate analysis on the effects of moderator variables on taper-induced performance changes in different modes of locomotion, substantial small-to-moderate improvements were only achieved when training intensity was not decreased during the taper in swimming [0.28 (0.08, 0.47)], running [0.37 (0.09, 0.66)] and cycling [0.68 (0.09, 1.27)]. In summary, the training load should not be reduced at the expense of training intensity during a taper, whatever the mode of locomotion (Bosquet et al., 2007).

The above-mentioned studies highlight the key role of training intensity during the taper. 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. (1982) 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. (1992) and Mujika et al. (2000) reported better physiological and performance outcomes with low-volume than with moderate-volume tapers. Bosquet et al. (2007) 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 (Fig. 1).

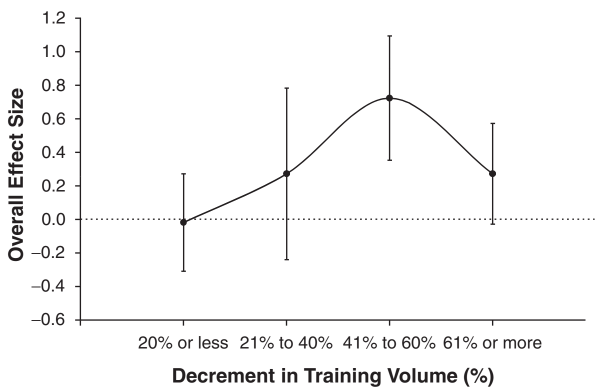

Fig. 1. Dose–response curve for the effect of percent decrement in training volume during the taper on performance. The magnitude of the difference (effect size) was considered either small (0.2), moderate (0.5) or large (0.8). Values are means and 95% confidence intervals. Reprinted by permission from Bosquet et al. (2007).

In summary, management of training intensity is key during the tapering phase of an individual sport-training program (Fig. 2). A taper characterized by reduced training could otherwise lead to a loss of training-induced adaptations and suboptimal performance.

Intense training in team sports

High-intensity exercise training is a crucial component of competition performance in team sports such as association football, rugby, field and ice hockey and basketball. In football, for instance, sprints, accelerations, rapid changes of direction and maximal jumps are game activities repeatedly performed at maximal or near maximal intensity to win an edge over opposing players and possession of the ball (Mohr et al., 2003). The amount of high-intensity exercise during match play in top-level professional football teams is partly determined by the playing position in relation to ball interaction, previous activity in the game, physical activity pattern displayed by the opposing team and their competitive level, as well as the overall technical and tactical effectiveness of the team (Rampinini et al., 2007; Di Salvo et al., 2009). Nevertheless, intense exercise remains a critical component of team sport performance, and optimizing players' ability to perform this type of effort should be a priority.

Dupont et al. (2004) were among the first to evaluate the effects of in-season high-intensity training on the running performance of professional male football players. Following a 10-week control period, two weekly high-intensity training sessions were integrated in the team's usual training for 10 weeks. High-intensity training consisted of intermittent runs of 12–15 s at 120% of maximal aerobic velocity interspersed with 15-s rest, and 12–15 maximal 40 m sprints with 30-s recovery. The intervention

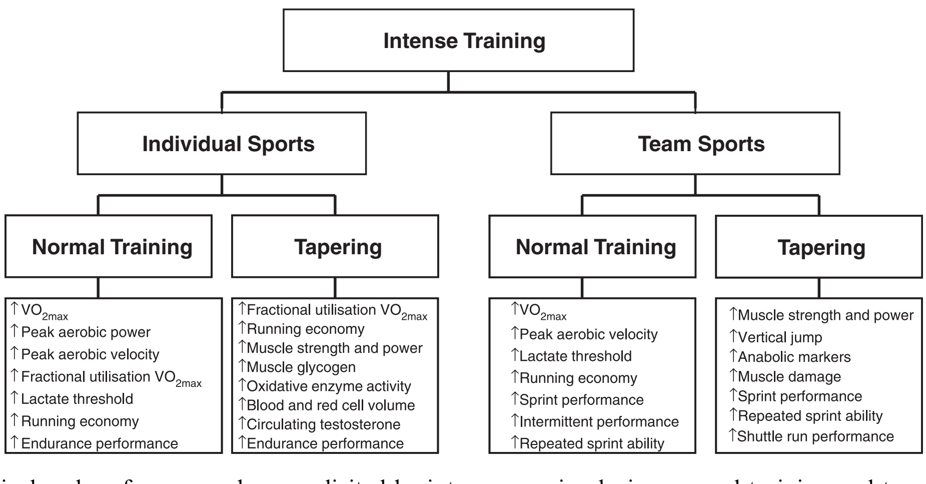

Fig. 2. Physiological and performance changes elicited by intense exercise during normal training and tapering in individual and team sports.

brought about an 8.1% improvement in maximal aerobic velocity and a 3.5% gain in 40 m sprint time. Although it is not entirely appropriate to directly link individual players' physical performance to a team's football performance, the team won 33% of its games during the 10-week control period preceding the intervention, and 78% during the high-intensity training phase.

In line with the above study, Impellizzeri et al. (2006) carried out a training intervention on junior football players to assess the effects of specific (small-sided games) and generic (running) high-intensity training on physical fitness and objective measures of match performance. Both training groups performed twice a week for 8 weeks four bouts of 4 min at 90–95% HR_{max} with 3 min active rest periods. After the intervention, markers of aerobic fitness such as VO_{2max}, lactate threshold and running economy at the lactate threshold increased, respectively, by 7%, 10% and 2%. Most importantly, the total distance covered during match play increased by 6% after the intervention, and the time spent performing high-intensity activities increased by 18%. Ferrari Bravo et al. (2008) also evaluated the effect of 7 weeks of twice per week high-intensity aerobic interval training (4 by 4-min running at 90–95% of HR_{max}) and repeated-sprint ability training (3 by 6 maximal 40 m shuttle sprints) on aerobic and anaerobic physiological variables in football players. Although both training interventions induced similar 6% and 3% gains in VO_{2max} and the ventilatory threshold, repeated-sprint ability training elicited larger improvements in the Yo-Yo Intermittent Recovery test, and only this training intervention resulted in performance gains in repeated-sprint ability.

Mujika et al. (2007) published a case study on a youth elite football player who had been underperforming for several months. The player completed a high-intensity individualized training program for 7 weeks, characterized by seven sessions of 4 by 4-min cycling and running repetitions at 90% of HR_{max}, followed by three sessions of 3 by 45 s of all out running. This program was implemented during normal team training time, but the player participated in the remaining team activities after completion of each individualized session. The high-intensity training intervention represented 9.5% of the total training time. An overall improvement in the player's Yo-Yo Intermittent Recovery Test performance of 32% could have facilitated a greater involvement of the player in other training activities. The improved physical fitness could also have facilitated gains in psychological factors such as confidence, which could further translate into objective and subjective match performance enhancements.

Taken together, these studies indicate that high-intensity activity is often a performance-determining factor during match play in a team sport setting. Moreover, research evidence shows that pre-season and in-season high-intensity training can elicit substantial gains in markers of aerobic fitness in already highly trained players, which can have a positive impact on competitive performance (Fig. 2).

Intense training and 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 (Mujika, 2007).

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. (2007) 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 10 m 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 (Coutts et al., 2007).

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. (2006) 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). Anecdotally, 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 (2003) 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 (Fig. 2). The relevant research studies indicate that a pre-tournament taper should be characterized by low-training volume and high-intensity activities.

Event intensity, multiple peaking and the taper

The duration of each particular sport or action within a sport determines its intensity and metabolic demands. Whether optimal tapering strategies vary depending on the demands of an athletic event and/or the physiological characteristics of the athletes taking part in that event has not been clearly established, but the available data suggest this not to be the case. Indeed, as can be seen in Fig. 2, an efficient taper induces physiological adaptations that simultaneously benefit aerobic and anaerobic power production. Taper-induced cardiorespiratory, metabolic, hormonal and neuromuscular changes are associated with similar performance gains in athletic events ranging from a few seconds to over an hour (Mujika et al., 2004). Moreover, no evidence is available to suggest that the intensity of an athletic event will determine the optimal duration of a taper. Bosquet et al. (2007) described a dose–response relationship between the duration of the taper and the performance improvement. Durations ranging from 8 to 14 days represented the borderline between fatigue disappearance and detraining. However, tapers lasting 1–4 weeks can also induce performance improvements, although negative results may be experienced by some athletes. The inter-individual variability in the optimal taper duration was not attributed to specific event intensity or an athlete's physiological characteristics.

Unfortunately, no study has examined the taper in the context of multiple peaking. In many individual sports, international competition involves a series of qualifying rounds and/or stages over several days. Most team sports competitions involve one or more games per week over a season lasting several months. Because of the lack of research in the area of multiple peaking, it is not known how often an athlete or team can obtain the performance benefits of an efficient taper, and it is not possible to make sound recommendations in this respect (Pyne et al., 2009).

Consensus statements

(1) There is strong evidence indicating that high-intensity training is associated with maximal physiological and performance adaptations during periods of intensive training in highly trained individual sport athletes.
(2) There is strong evidence indicating that training intensity is key to maintain and enhance physiological and performance adaptations during the taper, and hence the training load should not be reduced at the expense of intensity.
(3) Intense exercise is a critical component of team sport performance, and there is strong evidence to suggest that the optimization of the players' ability to perform this type of effort should be a priority.
(4) Limited available research suggests that team sport athletes could benefit from a high-intensity tapering

program to optimally prepare for the regular season and tournament style competition.
(5) The limited research available suggests that optimal tapering strategies do not depend on the intensity of an athletic event or the physiological characteristics of the athletes taking part in that event.

Key words: intensity, recovery, reduced training, team-sports.

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