

Scientific Bases for Precompetition Tapering Strategies

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ABSTRACT

MUJICA, I., and S. PADILLA. Scientific Bases for Precompetition Tapering Strategies. *Med. Sci. Sports Exerc.*, Vol. 35, No. 7, pp. 1182-1187, 2003. 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. The aim of the taper should be to minimize accumulated fatigue without compromising adaptations. This is best achieved by maintaining training intensity, reducing the training volume (up to 60–90%) and slightly reducing training frequency (no more than 20%). The optimal duration of the taper ranges between 4 and more than 28 d. Progressive nonlinear tapers are more beneficial to performance than step tapers. Performance usually improves by about 3% (usual range 0.5–6.0%), due to positive changes in the cardiorespiratory, metabolic, hematological, hormonal, neuromuscular, and psychological status of the athletes. **Key Words:** TAPER, TRAINING, REDUCED TRAINING, DETRAINING, PERFORMANCE

Athletes, coaches, and sports scientists throughout the world are increasingly pushing the limits of human adaptation and training loads with the aim of achieving top performances at the major competition of their respective sports. 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 of reduced training is generally known as the taper (2,8,17,19,27,28,35,38,44,49,50).

The taper is the final period of training before a major competition and is of paramount importance to an athlete's performance and the outcome of the event (3,19,28,32,34,37,41,45,46). 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 described some of the physiological changes associated with successful tapering programs, and increased their understanding of the relationships between taper-induced

performance improvements and concomitant cardiorespiratory (2,19,50), metabolic (2,3,19,38,50), hematological (33,34,36,44,49), hormonal (3,31–34), neuromuscular (19,22,46), and psychological (13,25,41,45,48) changes.

In an attempt to go beyond descriptive experimental procedures to analyze the consequences of the taper, some investigators have developed a mathematical modeling methodology purported to optimize individual tapering strategies (2,7,26,28,30). Meanwhile, a handful of intervention studies have reported on the physiological and performance consequences of experimental manipulations of taper programs (2,33,34,38,44,50).

A comprehensive and integrated analysis of the available scientific literature on tapering allows us to make a contribution to the optimization of tapering programs. Although we acknowledge that designing training and tapering programs remains an art rather than a science, this paper intends to establish the scientific bases for the precompetition tapering strategies. It is our hope that the following information helps individual athletes, coaches, and sports scientists in their goal of achieving the optimum training mix during the taper, leading to more peak performances at the expected time of the season.

DEFINITION OF TAPER

The taper has variously been defined as a "decrease in work level that the competitive swimmer undergoes during practice in order to rest and prepare for a good performance" (49); "a specialized exercise training technique which has been designed to reverse training-induced fatigue without a loss of the training adaptations" (38); "a reduction in train-

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Submitted for publication December 2002.

Accepted for publication February 2003.

0195-9131/03/3507-1182

MEDICINE & SCIENCE IN SPORTS & EXERCISE

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DOI: 10.1249/01.MSS.0000074448.73931.11

ing before competition" (44); "an incremental reduction in training volume for 7-21 d before a championship race" (17); "the short-term reduction in training load before competition" (8); and "a period of reduced training volume to enhance performance" (46).

Based on the body of data available in the sports science literature, the taper has been recently redefined as "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" (35). This definition, which encompasses and expands previous attempts, contains implications for the design of tapering strategies that need to be justified and further analyzed.

AIMS OF THE TAPER

According to the above cited definition of the taper, the main aim of this training phase is to reduce the negative physiological and psychological impact of daily training (i.e., accumulated fatigue), rather than achieve further improvements in the positive consequences of training (i.e., fitness gains). Indeed, Mujika et al. (28) analyzed the responses to three taper periods in a group of national and international level swimmers by means of a mathematical model, which computed fatigue and fitness indicators from the combined effects of a negative and a positive function representing respectively the negative and positive influence of training on performance (4,7). We observed that performance gains during the tapering periods were mainly related to marked reductions in the negative influence of training, coupled with slight nonsignificant increases in the positive influence of training (28). This suggests that, by the time they start tapering, athletes should have achieved most or all of the expected physiological adaptations, eliciting improved performance levels as soon as accumulated fatigue fades away and performance-enhancing adaptations become apparent.

Conclusions attained by mathematical procedures were supported by biological findings. In a subsequent study on competitive swimmers, Mujika et al. (32) reported a significant correlation between the percentage change in the testosterone/cortisol ratio and the percentage performance improvement during a 4-wk taper. It has been suggested that the plasma concentrations of androgens and cortisol represent anabolic and catabolic tissue activities, respectively (1). Because the balance between anabolic and catabolic hormones may have important implications on recovery processes after intense training bouts, the testosterone/cortisol ratio has been suggested as a marker of training stress (1). Accordingly, the observed increase in the testosterone/cortisol ratio during the taper, be it the result of an increased testosterone concentration subsequent to an enhanced pituitary response to the preceding period of intensive training (4,32,34) or a decreased cortisol concentration (3,31), would be indicative of enhanced recovery and elimination of accumulated fatigue.

Other biological indices of reduced training stress and increased recovery have been reported in the literature as a result of tapering periods. Several authors have shown increments in red cell volume, hemoglobin levels and hematocrit as a result of the taper (44,49), and these hematological indices have been shown to be related with taper-induced performance improvements (36). In line with the above results, serum haptoglobin has been shown to increase significantly during the taper (34). Haptoglobin is a glycoprotein that binds free hemoglobin released into the circulation to conserve body iron. Because of a rapid removal of the haptoglobin-hemoglobin complex from the blood by the liver, its levels are often below normal in highly trained endurance athletes, suggesting a chronic hemolytic condition (43) that would be reversed during the taper. Increased reticulocyte counts have also been observed at the end of tapering periods in middle-distance runners (33,34). Taken as a whole, the above results indicate that tapering periods in trained subjects are associated with a positive balance between hemolysis and erythropoiesis in response to the reduced training stress (17,33,34,36,39,44). Blood levels of creatine kinase, which have also been used as an index of training-induced physiological stress, have been shown to decrease in highly trained athletes as a result of the reduced training load that characterizes the tapering periods (24,49).

From a psychological perspective, tapering phases are often associated with performance-enhancing changes such as reduced perception of effort, reduced global mood disturbance, reduced perception of fatigue, and increased vigor (13,25,41). The taper has also been associated with an improvement in the quality of sleep in competitive swimmers (45). These psychological changes can also be interpreted as indices of enhanced recovery from the daily training stress.

REDUCTION OF THE TRAINING LOAD

The training load or training stimulus in competitive sports can be described as a combination of training intensity, volume, and frequency (47). This training load is markedly reduced during periods of taper in an attempt to reduce accumulated fatigue, but reduced training should not be detrimental to training-induced adaptations. An insufficient training stimulus could bring about a partial or complete loss of training-induced anatomical, physiological and performance adaptations, i.e., detraining (35). Therefore, it is of major importance to determine the extent to which the training load can be reduced at the expense of each of the above-mentioned training variables, while retaining or slightly improving adaptations and avoiding a fall into detraining.

Reduction of training intensity. In the third and last part of a now classic series of studies, Hickson et al. (10) demonstrated that training intensity is an essential requirement for maintaining training-induced adaptations during periods of reduced training in moderately trained individuals. These authors reported that gains in aerobic power, endurance measures, and cardiac growth attained

during 10 wk of intensive training could not be maintained for a subsequent 15-wk period during which training intensity was reduced by one third or two thirds, whereas training volume and frequency remained the same (10). The paramount importance of training intensity for the maintenance of training-induced physiological and performance adaptations has also been demonstrated in intervention studies performed with highly trained athletes. Shepley et al. (44) compared some of the physiological and performance effects of a high-intensity low-volume taper, a low-intensity moderate-volume taper, and a rest-only taper in middle-distance runners. Total blood volume, red cell volume, citrate synthase activity, muscle glycogen concentration, muscle strength, and running time to fatigue were optimized only with the high-intensity low-volume taper. In this respect, the major influence of training intensity on the retention or improvement of training-induced adaptations could be explained by its role in the regulation of concentrations and activities of fluid retention hormones (5,27). In addition, Mujika et al. (33) reported that high-intensity interval training during the taper correlated positively with the percentage change in circulating testosterone levels in a group of well-trained middle-distance runners tapering for 6 d. In their reviews, other authors have underlined the importance of training intensity during periods of taper (17,21,27,39).

Reduction of training volume. Moderately trained subjects appear to retain gains in maximal oxygen uptake, peak blood lactate concentrations, calculated left ventricular mass, and short-term endurance (exercise to exhaustion at an intensity corresponding to the maximal oxygen uptake) attained through 10 wk of training during 15 subsequent weeks of reduced training duration, during which training time was reduced by one or two thirds (11). Standardized training volume reductions of 50–70% have also been shown to be a valid approach to retain, or slightly improve, training-induced adaptations in well-trained runners (15,16,18,23) and cyclists (22,42). On the other hand, progressive training reductions of up to 85% have been reported to bring about various significant performance-enhancing physiological changes. Mujika et al. (33) compared the effects of progressive 50% or 75% training volume reductions during a 6-d taper in middle-distance runners and concluded that the 75% reduction was a more appropriate strategy to optimize adaptations. They also found a negative correlation between the distance of low-intensity continuous training and the percentage change in circulating testosterone during the taper.

In a similar group of runners, Shepley et al. (44) also found better physiological and performance results with a low-volume taper than with a moderate-volume taper. In competitive swimmers, a positive relationship has been observed between performance gains and the percentage reduction in training volume during a 3-wk taper (29). The beneficial consequences of significant progressive 50–90% reductions in training volume during the

taper have repeatedly been underpinned by several researchers in swimming (19,20,24,31,32,36,46,49), running (33,34), cycling (6,38), triathlon (2,38,50), and strength training (8). This same idea has also been stressed by others (17,27).

Reduction of training frequency. Hickson and Rosenkoetter (12) provided evidence that it is possible for recently trained individuals to maintain the 20–25% gains in maximal oxygen uptake attained during 10 wk of endurance training for at least 15 wk of reduced training frequency, whether this reduction amounted to one third or two thirds of previous values. Similar results have been observed in strength-trained subjects (9). Several physiological and performance measures are retained or improved as a result of 2- to 4-wk periods characterized by reduced training frequencies in cyclists, runners, and swimmers (15,16,18,22,23,40,42). Johns et al. (19) reported increased power and performance in competitive swimmers who reduced training frequency by 50% during 10 and 14 d of taper, and Dressendorfer et al. (6) observed a significant improvement in a 20-km cycling time trial simulation after a 50% reduction in training frequency during a 10-d taper.

On the other hand, the only available report that compared a high-frequency taper (maintenance of a daily training frequency) and a moderate-frequency taper (33% reduction in training frequency, i.e., resting every third day of the taper) in highly trained middle-distance runners concluded that training daily during a 6-d taper brought about significant performance gains in an 800-m race, whereas resting every third day of the taper did not. Given that no differences in the physiological responses to the taper were found between groups, in the absence of systematic psychometric measurements before and after the taper, and in accordance with previous suggestions (17,21,39), the authors attributed these results to a potential "loss of feel" during exercise (34). Taken together, all of the above results suggest that whereas training adaptations can be readily maintained with quite low training frequencies in moderately trained individuals (30–50% of pretaper values), much higher training frequencies should be recommended for the highly trained, especially in the more "technique-dependent" sports such as swimming (>80%).

DURATION OF THE TAPER

Assessing the most suitable duration of a taper for an individual athlete is one of the most difficult challenges for coaches and sports scientists. As a matter of fact, positive physiological, psychological, and performance adaptations have been reported as a result of taper programs lasting 4–14 d in cyclists and triathletes (2,6,21,22,38,50), 6–7 d in middle- and long-distance runners (33,34,44), 10 d in strength trained athletes (8), and 10–35 d in swimmers (3,19,24,28,29,31,32,36,37,41,45,46,49). Unfortunately, the time frame that separates the benefits of a successful taper from the negative consequences of insufficient training

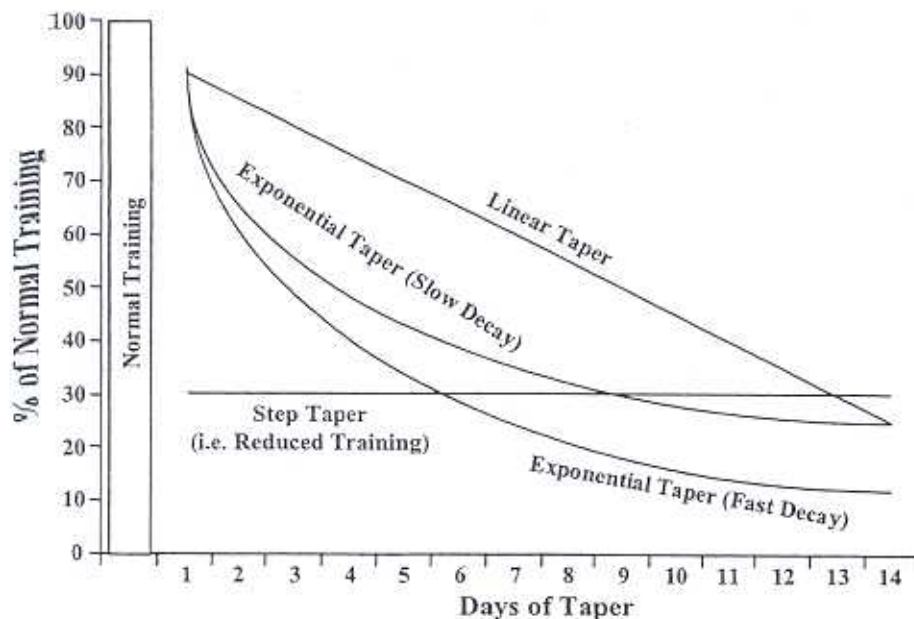


FIGURE 1—Schematic representation of the different types of tapers: linear taper, exponential taper with slow or fast time constants of decay of the training load, and step taper (also referred to as reduced training).

(35,39) has not been clearly established. Based on changes in blood lactate concentration and performance times derived from a test work set, Kenitzer (20) concluded that a taper of approximately 2 wk represented the limit of recovery and compensation time before detraining became evident in a group of female swimmers. Kubukely et al. (21) recently suggested that the optimum taper duration may be influenced by previous training intensity and volume, with athletes training harder and longer requiring roughly 2 wk to fully recover from training while maximizing the benefits of training, and those who reduce their amount of high-intensity training needing a shorter taper to prevent a loss of fitness.

Some authors have used mathematical modeling methodology in an attempt to optimize tapering strategies for each individual athlete, including optimal taper duration (7,26,28,30). In one of these studies, the theoretical optimal taper duration in a group of national and international level swimmers ranged between mean values of 12 and 32 d, with a great intersubject variability (28), which leads to the conclusion that taper duration must be individually determined for each athlete, in accordance with their specific profiles of adaptation to training on the one hand, and loss of training-induced adaptations on the other hand.

TYPE OF TAPER

Four different types of tapers have been described and used in the past in an attempt to optimize sports performance. These are visually described in Figure 1. The training load during the taper is usually reduced in a progressive manner, as implied by the term taper. This reduction can be carried out either linearly or exponentially. As shown in Figure 1, a linear taper implies a higher training load than an exponential taper. In addition, an exponential taper can have either a slow or a fast time constant of decay, the training load being higher in the slow decay taper. Nonprogressive standardized reductions of the training load

have also been used (Fig. 1). This reduced training procedure, which may maintain or even improve many of the physiological and performance adaptations gained with training (9,10–12,15,16,18,22,23,27,40) is also referred to as step taper (2,27,50).

Despite the popularity of both the progressive and nonprogressive approaches to tapering, only one intervention study is available in the literature that has actually compared their performance consequences in highly trained athletes. Such a study was performed on a group of highly trained triathletes, who after 3 months of intensive training, were initially asked to perform either a 10-d taper in which the training load was reduced exponentially or a step taper of the same duration. The exponential taper brought about a 4.0% improvement in an all-out 5-km criterion run and a 5.4% increase in peak power output measured in a ramp cycling test to exhaustion. In contrast, the step taper produced nonsignificant improvements of 1.2% and 1.5%, respectively. After six additional weeks of intensive training, subjects were asked to perform a 13-d exponential taper, in which the time constant of decay in training volume was either fast ($\tau = 4$ d) or slow ($\tau = 8$ d). The fast exponential taper resulted in 6.3% and 7.9% improvements in the above-mentioned criterion performance measures, whereas improvements with the slow exponential taper were 2.4% and 3.8%. The authors concluded that an exponential taper was a better strategy to enhance performance than a step taper and that the fast decay protocol (i.e., low-volume taper) was more beneficial to performance than the slow decay protocol (2,50).

EXPECTED PERFORMANCE IMPROVEMENTS

The final and major goal of a taper is to optimize competition performance. Most studies dealing with progressive tapers in athletes have reported significant performance improvements in various sports including swimming, running, cycling, and triathlon. Some have determined performance changes in actual competition

(3,28,29,31-34,36,37,41,45,46), whereas some others report on laboratory or field-based criterion performance measures (2,6,8,13,19,20,38,44,50). These performance gains, which have variously been attributed to increased levels of muscular force and power, improvements in neuromuscular, hematological, and hormonal function, and psychological status of the athletes, are usually in the range of 0.5-6.0% for competition performance measures but can reach up to 25% in noncompetitive criterion measures. In this respect, it is important to establish the validity of the performance tests and their relationship with actual performance in a specific competition event (14).

In a recent investigation, Mujika et al. (37) reported an overall swimming performance improvement of 2.2% during the final 3 wk of training in the lead-up to the Sydney 2000 Olympic Games. Interestingly, the magnitude of the improvement was similar for all competition events and was achieved by swimmers from different countries and performance levels. In addition, the observed swim time improvement was considered very worthwhile in performance terms, as the differences between the gold medalist and the first swimmer out of the medals, and between the bronze medal winner and the last swimmer in the final at the Olympic events were smaller than the mean improvement in swim time obtained during the taper. As a whole, the above-reported performance change data provide a quantitative framework for coaches and athletes to set realistic performance goals based on individual performance levels before the tapering phase leading to important competitions.

CONCLUSIONS AND PRACTICAL IMPLICATIONS

Based on the data presented in the above sections, the following conclusions and practical implications for optimum tapering strategies can be drawn (Table 1):

1. The primary aim of the taper should be to minimize accumulated fatigue, rather than to attain additional physiological adaptations or fitness gains. This goal should be

REFERENCES

- ADLERCREUTZ, H., M. HÄRKÖNEN, K. KUOPPASALMI, et al. Effect of training on plasma anabolic and catabolic steroid hormones and their response during physical exercise. *Int. J. Sports Med.* 7:27-28, 1986.
- BANISTER, E. W., J. B. CARTER, and P. C. ZARKADAS. Training theory and taper: validation in triathlon athletes. *Eur. J. Appl. Physiol.* 79:182-191, 1999.
- BONFAZI, M., F. SARDELLA, and C. LUPPO. Preparatory versus main competitions: differences in performances, lactate responses and pre-competition plasma cortisol concentrations in elite male swimmers. *Eur. J. Appl. Physiol.* 82:368-373, 2000.
- BUSO, T., K. HAKKINEN, A. PAKARINEN, H. KAUKANEN, P. V. KOMI, and J. R. LACOUR. Hormonal adaptations and modelled responses in elite weightlifters during 6 weeks of training. *Eur. J. Appl. Physiol.* 64:381-386, 1992.
- CONVERTINO, V. A., C. KEIL, and J. E. GREENLEAF. Plasma volume, osmolality, vasopressin, and renin activity during graded exercise in man. *J. Appl. Physiol.* 50:123-128, 1981.
- DRESENDORFER, R. H., S. R. PETERSEN, S. E. MOSS LOVSHIN, and C. L. KEEN. Mineral metabolism in male cyclists during high-intensity endurance training. *Int. J. Sport Nutr. Exerc. Metab.* 12:63-72, 2002.

TABLE 1. Summary of optimal tapering strategies.

Tapering Strategy
Minimize fatigue without compromising fitness
Maintain training intensity
Reduce training volume by 60-90%
Maintain training frequency at >80%
Individualize taper duration between 4 and 28 d
Use progressive, nonlinear tapering designs
Expect performance improvements of ~3% (range 0.5-6.0%)

achieved without compromising previously acquired adaptations and fitness level.

2. The maintenance of training intensity (i.e., "quality training") is necessary to avoid detraining, provided that reductions in the other training variables allow for sufficient recovery to optimize performance.

3. Reductions in training volume as high as 60-90% appear to induce positive physiological, psychological and performance responses in highly trained athletes.

4. High training frequencies seem to be necessary to avoid detraining and/or "loss of feel" in the highly trained (>80%). On the other hand, training-induced adaptations can be readily maintained with very low training frequencies in moderately trained individuals (30-50%).

5. Positive physiological and performance adaptations can be expected as a result of tapers lasting 4-28 d, yet the negative effects of complete inactivity are readily apparent in athletes.

6. Progressive, nonlinear tapering techniques seem to have a more pronounced positive impact on performance than step-taper strategies.

7. Tapering strategies are usually effective at improving performance, but they do not work miracles! A realistic performance goal for the final taper should be a competition performance improvement of about 3% (usual range 0.5-6.0%).

The authors would like to express their gratitude to Dr. David Pyne of the Department of Physiology, Australian Institute of Sport for his valuable comments and suggestions.

- FITZ-CLARKE, J. R., R. H. MORTON, and E. W. BANISTER. Optimizing athletic performance by influence curves. *J. Appl. Physiol.* 71:1151-1158, 1991.
- GIBALA, M. J., J. D. MACDOUGALL, and D. G. SALE. The effects of tapering on strength performance in trained athletes. *Int. J. Sports Med.* 15:492-497, 1994.
- GRAVES, J. E., M. L. POLLOCK, S. H. LEGGETT, R. W. BRAITH, D. M. CARPENTER, and L. E. BISHOP. Effect of reduced training frequency on muscular strength. *Int. J. Sports Med.* 9:316-319, 1988.
- HICKSON, R. C., C. FOSTER, M. L. POLLOCK, T. M. GALASSI, and S. RICH. Reduced training intensities and loss of aerobic power, endurance, and cardiac growth. *J. Appl. Physiol.* 58:492-499, 1985.
- HICKSON, R. C., C. KANAKIS, JR., J. R. DAVIS, A. M. MOORE, and S. RICH. Reduced training duration effects on aerobic power, endurance, and cardiac growth. *J. Appl. Physiol.* 53:225-229, 1982.
- HICKSON, R. C., and M. A. ROSENKOETTER. Reduced training frequencies and maintenance of increased aerobic power. *Med. Sci. Sports Exerc.* 13:13-16, 1981.

13. HOOPER, S. L., L. T. MACKINNON, and A. HOWARD. Physiological and psychometric variables for monitoring recovery during tapering for major competition. *Med. Sci. Sports Exerc.* 31:1205-1210, 1999.
14. HOPKINS, W. G., J. A. HAWLEY, and L. BURKE. Design and analysis of research on sport performance enhancement. *Med. Sci. Sports Exerc.* 31:472-485, 1999.
15. HOUMARD, J. A., D. L. COSTILL, J. B. MITCHELL, S. H. PARK, W. J. FRUK, and J. M. BURNS. Testosterone, cortisol, and creatine kinase levels in male distance runners during reduced training. *Int. J. Sports Med.* 11:41-45, 1990.
16. HOUMARD, J. A., D. L. COSTILL, J. B. MITCHELL, S. H. PARK, R. C. HECKNER, and J. N. ROEMMICH. Reduced training maintains performance in distance runners. *Int. J. Sports Med.* 11:46-52, 1990.
17. HOUMARD, J. A., and R. A. JOHNS. Effects of taper on swim performance: practical implications. *Sports Med.* 17:224-232, 1994.
18. HOUMARD, J. A., J. P. KIRWAN, M. G. FLYNN, and J. B. MITCHELL. Effects of reduced training on submaximal and maximal running responses. *Int. J. Sports Med.* 10:30-33, 1989.
19. JOHNS, R. A., J. A. HOUMARD, R. W. KOBE, et al. Effects of taper of swim power, stroke distance and performance. *Med. Sci. Sports Exerc.* 24:1141-1146, 1992.
20. KINITZER, R. F., Jr. Optimal taper period in female swimmers. *J. Swimming Res.* 13:31-36, 1998.
21. KUBUKELI, Z. N., T. D. NOAKES, and S. C. DENNIS. Training techniques to improve endurance exercise performances. *Sports Med.* 32:489-509, 2002.
22. MARTIN, D. T., J. C. SCIFRES, S. D. ZIMMERMAN, and J. G. WILKINSON. Effects of interval training and a taper on cycling performance and isokinetic leg strength. *Int. J. Sports Med.* 15:485-491, 1994.
23. MCCONELL, G. K., D. L. COSTILL, J. J. WIDRICK, M. S. HICKNEY, H. TANAKA, and P. B. GASTIN. Reduced training volume and intensity maintain aerobic capacity but not performance in distance runners. *Int. J. Sports Med.* 14:33-37, 1993.
24. MILLARD, M., C. ZAUNER, R. CADE, and R. REESE. Serum CPK levels in male and female world class swimmers during a season of training. *J. Swimming Res.* 1:12-16, 1985.
25. MORGAN, W. P., D. R. BROWN, J. S. RAGLIN, P. J. O'CONNOR, and K. A. ELLICKSON. Psychological monitoring of overtraining and staleness. *Br. J. Sports Med.* 21:107-114, 1987.
26. MORTON, R. H., J. R. FITZ-CLARKE, and E. W. BANISTER. Modeling human performance in running. *J. Appl. Physiol.* 69:1171-1177, 1990.
27. MUJKA, I. The influence of training characteristics and tapering on the adaptation in highly trained individuals: a review. *Int. J. Sports Med.* 19:439-446, 1998.
28. MUJKA, I., T. BUSO, A. GEYSSANT, F. BARALE, L. LACOSTE, and J. C. CHATARD. Modeled responses to training and taper in competitive swimmers. *Med. Sci. Sports Exerc.* 28:251-258, 1996.
29. MUJKA, I., J. C. CHATARD, T. BUSO, A. GEYSSANT, F. BARALE, and L. LACOSTE. Effects of training on performance in competitive swimming. *Can. J. Appl. Physiol.* 20:395-406, 1995.
30. MUJKA, I., J. C. CHATARD, T. BUSO, A. GEYSSANT, F. BARALE, L. LACOSTE. Use of swim-training profiles and performance data to enhance training effectiveness. *J. Swimming Res.* 11:23-29, 1996.
31. MUJKA, I., J. C. CHATARD, and A. GEYSSANT. Effects of training and taper on blood leucocyte populations in competitive swimmers: relationships with cortisol and performance. *Int. J. Sports Med.* 17:213-217, 1996.
32. MUJKA, I., J. C. CHATARD, S. PADILLA, C. Y. GUEZENNEC, and A. GEYSSANT. Hormonal responses to training and its tapering off in competitive swimmers: relationships with performance. *Eur. J. Appl. Physiol.* 74:361-366, 1996.
33. MUJKA, I., A. GOYA, S. PADILLA, A. GRUJALBA, E. GOROSTIAGA, and J. IBAÑEZ. Physiological responses to a 6-day taper in middle-distance runners: influence of training intensity and volume. *Med. Sci. Sports Exerc.* 32:511-517, 2000.
34. MUJKA, I., A. GOYA, E. RUIZ, A. GRUJALBA, J. SANTISTEBAN, and S. PADILLA. Physiological and performance responses to a 6-day taper in middle-distance runners: influence of training frequency. *Int. J. Sports Med.* 23:367-373, 2002.
35. MUJKA, I., and S. PADILLA. Detraining loss of training-induced physiological and performance adaptations. Part I. Short-term insufficient training stimulus. *Sports Med.* 30:79-87, 2000.
36. MUJKA, I., S. PADILLA, A. GEYSSANT, J. C. CHATARD. Hematological responses to training and taper in competitive swimmers: relationships with performance. *Arch. Physiol. Biochem.* 105:379-385, 1997.
37. MUJKA, I., S. PADILLA, and D. PYNE. Swimming performance changes during the final 3 weeks of training leading to the Sydney 2000 Olympic Games. *Int. J. Sports Med.* 23:582-587, 2002.
38. NEARY, J. P., T. P. MARTIN, D. C. REID, R. BURNHAM, and H. A. QUINNEY. The effects of a reduced exercise duration taper programme on performance and muscle enzymes of endurance cyclists. *Eur. J. Appl. Physiol.* 65:30-36, 1992.
39. NEUFER, P. D. The effect of detraining and reduced training on the physiological adaptations to aerobic exercise training. *Sports Med.* 8:302-321, 1989.
40. NEUFER, P. D., D. L. COSTILL, R. A. FIELDING, M. G. FLYNN, and J. P. KIRWAN. Effect of reduced training on muscular strength and endurance in competitive swimmers. *Med. Sci. Sports Exerc.* 19:486-490, 1987.
41. RAGLIN, J. S., D. M. KOCEJA, J. M. STAGER, and C. A. HARMS. Mood, neuromuscular function, and performance during training in female swimmers. *Med. Sci. Sports Exerc.* 28:372-377, 1996.
42. RIETJENS, G. J. W. M., H. A. KEIZER, H. KUIPERS, and W. H. M. SARIS. A reduction in training volume and intensity for 21 days does not impair performance in cyclists. *Br. J. Sports Med.* 35:431-434, 2001.
43. SELBY, G. B., and E. R. EICHNER. Endurance swimming, intravascular hemolysis, anemia, and iron depletion. *Am. J. Med.* 81:791-794, 1986.
44. SHEPLEY, B., J. D. MACDOUGALL, N. CIPRIANO, J. R. SUTTON, M. A. TARNOPOLSKY, and G. COATES. Physiological effects of tapering in highly trained athletes. *J. Appl. Physiol.* 72:706-711, 1992.
45. TAYLOR, S. R., G. G. ROGERS, and H. S. DRIVER. Effects of training volume on sleep, psychological, and selected physiological profiles of elite female swimmers. *Med. Sci. Sports Exerc.* 29:688-693, 1997.
46. TRAPPE, S., D. COSTILL, and R. THOMAS. Effect of swim taper on whole muscle and single fiber contractile properties. *Med. Sci. Sports Exerc.* 32:48-56, 2001.
47. WENGER, H. A., and G. J. BELL. The interactions of intensity, frequency and duration of exercise training in altering cardiorespiratory fitness. *Sports Med.* 3:346-356, 1986.
48. WITTING, A. F., J. A. HOUMARD, and D. L. COSTILL. Psychological effects during reduced training in distance runners. *Int. J. Sports Med.* 10:97-100, 1989.
49. YAMAMOTO, Y., Y. MUTOH, and M. MIYASHITA. Hematological and biochemical indices during the tapering period of competitive swimmers. In: *Swimming Science V*, B. E. Ungerechts, K. Wilke, and K. Reischle (Eds.). Champaign, IL: Human Kinetics, 1988, pp. 269-275.
50. ZARKADAS, P. C., J. B. CARTER, and E. W. BANISTER. Modelling the effect of taper on performance, maximal oxygen uptake, and the anaerobic threshold in endurance triathletes. *Adv. Exp. Med. Biol.* 393:179-186, 1995.