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TAPERING FOR TRIATHLON: CURRENT CONCEPTS, EFFECTS, AND APPLICATIONS

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Abstract

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Tapering for Triathlon: Current Concepts, Effects, and Applications

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The practice of tapering for competition is an integral component of training for triathlon competition. Coaches and athletes alike need to understand where tapering is effective and under what conditions in order to optimize race performance. Triathlon training poses some distinctive challenges for coaches in that it encompasses multiple sub disciplines and likewise presents special challenges in scientific evaluation. This review of both scientific and lay literature sought to evaluate the present state of tapering in academic, coaching, and athletic practices in order to guide present and future recommendations and investigations. Searches for key terms were performed in PubMed, an internet search engine, and the University of Montana catalog database to identify publications on triathlon and related sub disciplines. Other relevant resources were included in the review as they were uncovered during the process. This review approach considered what information was actually reaching end consumers through different channels of communication as well as the role of individual experience. Findings suggest a confluence of evidence for triathlon and subdisciplines that constitute endurance events. The swimming component of triathlon was not evaluated as an independent variable in any of the triathlon-specific studies. Evidence suggests that tapering can effectively enhance race performance when following a period of training overload. Overall evidence consistently favored progressive tapering with training frequency maintained at >= 80 % and no decrease in intensity. Opinions expressed by coaches were varied and sometimes specific to the distance but not necessarily based directly on scientific evidence. Ultimately the needs of the individual athletes can be established through monitoring responses the training cycle and outcomes of tapering practices. To optimize athlete performance coaches should work with the athletes to construct compatible training strategies. Future research questions should address how different training and race variables affect optimal tapering strategies as well as swimming training specific to triathlons.

Introduction

Tapering is the pre-competition practice of reducing training load to reduce physical and psychological stress from training and promote recovery for optimal performance. Tapering methods may consist of reducing training frequency, duration, intensity, or some combination of the above and vary partly with the sport. The tapering period immediately precedes competition (3).

Triathlon is a multidisciplinary sport that traditionally combines the sports of swimming, cycling, and running in succession. As such, the training and evaluation of training methods is more complex than with the sub-disciplines therein. Nonetheless, reducing training load through tapering is an established training practice for optimizing athletic performance during triathlon competition. Questions surround the impact of tapering practices of one sub discipline on the other sub disciplines, and the ultimate overall impact on performance. Views of where the benefits directly manifest are varied, and may encompass one or more body systems. For example, in Lore of Running: Second Edition, Tim Noakes speculated that the major benefits of tapering are in the brain, but doesn't completely dismiss other systems involved. In order to have a foundational framework for constructing a tapering plan, clarification may be needed to determine whether some or all of the benefits of tapering result from changes in physiology, biomechanics, the mind, or any component of training and performance. In turn, the practical implications are ultimately what matter to performance. Researchers, both in the laboratory and in the field, have attempted to determine which of these tapering methods optimize athletic performance (3,14,23,24,63,64). Frequency, duration, intensity, and patterns of load reduction have all been manipulated in research protocols. The authors' findings have varied with study design. Moreover, coaching practices do not always reflect research findings nor needs expressed by the athletes. My own experience through trial and error has been somewhat at odds with advice expressed in lay resources for triathletes.

With triathlon as a newly sanctioned NCAA sport, coaches will have different stakes now with the performance of collegiate teams rather than individuals. The new team race schedules may shape an unfamiliar macrocycle that needs a new approach to drafting training plans. In turn, coaching practices for other athletes and different distances will have equally relevant questions surrounding the unloading of training loads to optimize race performance. The focus of the coach's proteges will be more narrowly focused on particular distances and courses. A review of best practices will be needed to guide coaches into race preparations with due consideration to health and performance guidelines from the American College of Sports Medicine as well as the existing evidence on triathlon-specific performance. Likewise, the coaches will need to understand the common denominators of successful tapering and the various objectives therein that are tantamount to performance.

Regardless of the race distances during the season or the body of competition, the athletes and coaches alike will benefit from understanding tapering and knowing the best approaches to constructing an effective tapering cycle.

Rationale

The concept of tapering is familiar to athletes and coaches alike. However, recommendations and practices are varied across different resources and institutions. To get the most out of training, the athletes and the coaches need some understanding of the purpose, mechanisms, and evaluation of outcomes. Because there is some training and fitness overlap between triathlon and the corresponding subdisciplines, this review will explore research from subdisciplines to identify applicable findings. Some of these training and performance parameters include physiology, biomechanics, and motivation. While the training and tapering practices for vastly different distances may not be directly transferable from one distance to another, coaches might be able to extrapolate plans to one particular race distance by understanding the goals of tapering and mechanisms of enhanced performance. Herein, I will review available research on all of the above and attempt to identify what has yet to be determined.

Impact of Review

Coaches must have access to evidence-based practices to best prepare future intercollegiate triathletes and optimize the performance of all levels of triathletes they coach. More specifically triathlon coaches will need to identify the applicability of different tapering strategies across the sub disciplines. To prepare the athlete for future intense training bouts and racing, recovery monitoring may need to shift more towards an active process. Training plans cannot a purely prewritten, structured process if the athlete is to capitalize on their own strengths and overcome their weaknesses. To optimize athletic performance, modification and execution of athlete training prescription should reflect the relationship between athlete training, recovery, and performance. Training prescription should underscore mechanisms of performance enhancement, while being adaptable to differences in responsiveness to training and recovery across different athletes.

Tapering strategies among triathletes have been adopted most frequently from coaches, followed by books, journals, and fellow athletes (14). As people turn to coaches for formal training advice, coaches will need solid evidence-based recommendations to promote maximal performance in the triathlon. Given the many possible different approaches to tapering and different interpretations of evidence, prescriptions from coaches have been varied. Studies in running, swimming, and triathlon have highlighted the effectiveness of appropriate training intensity, volume, and patterns of training load reduction (3,19,23,24,34,35).

Pre-written training plans are a common practice with commercial coaching. For example, on the popular training website TrainingPeaks, the athletes can use a search option to find coaches and training plans. Tapering strategies therein may gloss over individual athlete responses to training practices. Commercially viable methods may need to be evaluated for effectiveness and scientific soundness in order to enhance the race performance of the athlete and maintain the relationship between the athlete and the coach.

The primary purpose of this review is to guide coaches and athletes towards evidence-based and empirical tapering and maximizing benefits for race performance in triathlons consisting of swimming, cycling, and running by examining concepts, physiologic and psychologic mechanisms of impact and monitoring, outcomes from research, and various opinions expressed by coaches and authors accessible to athletes. A secondary purpose of this review is to provide recommendations for future research on tapering for triathlon performance. Cross triathlons, winter triathlons, other triathlon format variations, and strength training practices are beyond the scope of this review.

Definitions

Triathlon: The sport that combines swimming, cycling, and running (in this context)

-Sprint: 750 m swim, 20 km ride, 5 km run

-Olympic: 1500 m swim, 40 km ride, 10 km run

-half (Ironman 70.3): 1.9 km swim, 89.6 km ride, 21.0 km run

-full (Ironman): 3.8 km swim, 179.2 km ride, 41.9 km run

Taper: Reduction of training duration, frequency, or intensity preceding competition

CSA: Cross sectional area (of skeletal muscle)

Efficiency: The ratio of the energy consumption of exercise to the work output

Economy: Oxygen required to sustain a constant velocity

Nonprogressive taper: a taper involving only a single reduction in training load

Progressive taper: a taper involving multiple steps in reducing the training load

Exponential taper: a progressive taper with the fastest reduction in volume at the beginning of the period

Slow decay: maintenance of relatively high training load across the exponential period

Fast decay: greater reduction of training load across the exponential period

Linear taper: a progressive taper with a fixed rate of load reduction

Stepwise taper: a progressive taper with incremental load reduction

Mean corpuscular volume: mean red blood cell volume

Search Methods

Whereas the purpose of this review is to elucidate methods and components of triathlon training relevant to coaches and athletes, literature cited herein must be relevant to actual triathletes. Articles were sought for relevance to tapering for triathlons as well as the sub disciplines with overlapping physiologic, psychologic, and preparatory processes. Additional inquiries related to the opinions and practices of active triathlon coaches.

The biomedical database PubMed was searched for relevant terms. This database was chosen for its breadth of material with a scientific journal focus. Also, citations of found articles were reviewed additional information and details. Also, original citations from textbooks were reviewed for details related to tapering, sports performance, and metabolism where appropriate. Any other resources cited by other resources or turning up in the search process were reviewed and included as needed.

PubMed search general terms for tapering included:

Triathlon taper/tapering

Swim/swimming taper/tapering

Cycle/cycling taper/tapering

Run/running taper/tapering

Marathon taper/tapering

Additionally, terms for psychological impact of tapering were searched separately, with terms as advised by a committee member:

Mood + Sport tapering

Psychometrics + sport tapering

Interdisciplinary + sport tapering

Profile of Mood States + tapering

RESTQ-76 Sport + tapering

Relevant articles submitted by the committee were also included.

Inclusion criteria for journal articles were prospective or retrospective research related to either triathlon or the sub disciplines. The included articles addressed key questions about the practices of high-performance athletes, and articles addressing key questions therein regarding training response cycles and parameters of athletic performance. A total of 63 articles were included for review.

Additionally, a Google search was performed for websites featuring tapering-relevant articles or blog posts from the NCAA triathlon and other USA Triathlon certified coaches. Inclusion criteria included all practicing coaching testimony and advice.

Limitations of Existing Research

Conclusions from published research are affected by the parameters set for the investigation. Difficulties of research on tapering include the relatively small percentage difference made by the taper, which render comparisons between individuals in field research potentially spurious when looking at race performances. Other variables leading up to the race may more closely explain performance changes. Studies need to be controlled and randomized to reliably assess tapering methods before applying to the population at large. Also, triathlon swimming is theoretically submaximal unlike single discipline swimming (45). Peeling, Bishop, and Landers (2005) found that submaximal swims optimized time trial performance in simulated sprint triathlons. This trial found that 80% maximal swimming outperformed 90 and 100 % swimming. This difference in the swim component itself and the interactions with other sub disciplines may make the swimming component of a research protocol difficult to isolate and link to overall performance. Additionally, an actual increase in performance of 2 – 8 % may be unrealistic in the real world due to the heterogeneity of race courses, the effects of travel distances, altered sleep patterns for larger races, and other variables leading into the big race of the year. More generally, limitations of research on periodization may need to be considered. A previous review on tapering in endurance athletes discussed evidence favoring undulating periodization for strength and power athletes, but noted that no such pattern has been published in any investigation on endurance performance (17). Another review highlighted the limitations of periodization research in failure to control other variables, such as nutrition, that could impact performance. Further the authors note that the existing research on periodization failed to predict “direction, timing, and magnitude” of changes with tapering and failed to distinguish between periodization and variation in the training plans (1). Thus, performance changes during training cycles could be a result psychological stimuli from the novelty of change. The review herein will focus on methods of and changes observed following tapering as it ties into triathlon training.

Review of the Literature

Performance Components and the Role of Tapering

Components of triathlon performance include aerobic fitness, anaerobic fitness, force production, speed, and a myriad of skills including swim form, bike cornering, and mounting and dismounting of the bike. Performance gains from training all of the above fitness parameters require appropriate rest and recovery to complete the training response cycle. Because the physical exertion of the three triathlon sub disciplines has different effects on the body systems, the specific needs for recovery in each may differ. Running involves impact and ground reaction forces and greater levels of eccentric contractions than cycling (4,28,46). Running performance is partly a function of internal muscle forces interacting with ground reaction forces not found in cycling or open water swimming (51).

As differences in placement among athletes can be measured in seconds, tapering has been an essential component of a successful training program for athletic competition (3,24,37,38,43,56,58,60,63,65). Tapering strategies have had durations ranging from four to 35 days (64). Reducing training load has led to enhanced performance in the range of 2 to 8 % (30,37,38).

Effects of Tapering Strategies Across Disciplines

Using six databases, Bosquet, Montpetit, Arvisais, Mujika (2007) performed a meta-analysis of swimming, cycling, and running tapering studies. The search terms used were "(taper* AND (performance* OR competition* OR training) AND (sport* OR exercise* OR swim* OR cycling* OR running* OR rowing*)." The inclusion criteria included competitive athletes as subjects, all intervention studies, field or competition based evaluation, and include all of the necessary data to calculate effect size. Exclusion criteria included previously reported data. Results were not calculated for specific distances. The authors concluded the optimal volume reduction was 41 – 60 % with training intensity and frequency maintained over 14 days. However, the findings of the studies were widely varied. The authors found insufficient data to determine the optimal speed or pattern of training load reduction, but concluded that progressive tapers appear to be superior to step tapers (6).

Intensity

Swimming

Trinity, Pahnke, Reese, and Coyle (2006) evaluated the pattern of power over the course of a training period in swimmers leading up to a conference competition and a subsequent national championship. This training structure for the period was a tapering protocol for each of two groups corresponding to a conference competition and a national championship. In the above study, training dropped from 80 % of overload in the first week, to 67 % for Week Two to 42 % for Week 3 (Peak) in the first taper period of the national championship protocol. The high-intensity training consisted of 15, 20, and 20 % of the volume from the high-volume period, Week 1 of Taper 1, and Week 2 of Taper 2 respectively. A second four-week taper period followed immediately after the first with 67 % of overload for Week 1, 50 % of overload for Week 2, 42 % of overload for Week 3, and 34 % for Week 4 (Peak). High-intensity training for the second phase consisted of 10, 15, and 10 % of the total volume for Week 1, 2, and 3 of the taper period. The effects observed included a 10.2 % increase in power and a 7.4 % increase in torque above the overload period following taper. In the second phase peak power represented a 11.6 % increase over the preceding high-volume period. Swim performance improvements of 4.7 and 4.5 % were found for the two respective peaks (72). The observations don't appear to link the high-intensity components of tapers directly to performance in competition but rather moderately link power and torque to performance.

Trinity, Pahnke, Sterkel, and Coyle (2008) evaluated the effects of low-intensity vs. high-intensity training during taper on power, torque, velocity at maximum power, and time in collegiate female swimmers leading up to conference and national championships (71). Subjects were in the top 40 in the NCAA for their respective best events. Training included a high-volume period where training was daily with 2 to 3 days of twice daily workouts per day, which were progressively removed in the taper period. The two training strategies both involved high-intensity training, albeit at different volumes. This data compared the first season's low-intensity taper strategy to the next season's high-intensity strategy for effectiveness in maximizing power, torque, velocity, and performance. Both strategies resulted in equal performances at the championships but the high-intensity taper maintained power more effectively. While race performance was not enhanced, the relationship between power and race performance in different events warrants clarification before power enhancement is a pivotal objective in tapering strategies. Power was 8 to 14 % higher with the high-intensity taper than the low-intensity taper at every except one point in Week 2. Overall, the research has consistently found that intensity must be at least maintained if not increased. The one meta-analysis, included in this review, by Bosquet et al. (2007) concluded the largest effect sizes were in tapers with maintained intensities (0.33 vs. -0.02), as such showing the greatest impact on experimental outcomes. Further details were not provided by the meta-analysis. Implications are unclear, as the number of subjects in the decreased intensity experiments was considerably lower than the maintained intensity subjects, and the effect sizes had quite a wide range. The standard deviations could reflect number of studies meeting inclusion criteria and experimental designs.

Cycling

Bosquet et al. (2007) found that among the 6 studies included for analysis, those that did not decrease intensity had largest effect size for performance enhancement (0.68 vs 0.25 for decreased intensity). The effect size in this meta-analysis measures the statistical impact across different tapering approaches (See table below). While the number of subjects involved in studies that met the criteria were far fewer. Nonetheless, the observed effects fit the confluence of research surrounding removing fatigue while maintaining a training stimulus.

TABLE 2. Effects of moderator variables on effect size for taper-induced changes in swimming, running, and cycling performance.

	Swimming		Running		Cycling	
Categories	**Mean (95% CI)**	***N***	**Mean (95% CI)**	***N***	**Mean (95% CI)**	***N***
Decrease in training volume						
≤ 20%	−0.04 (−0.36, 0.29)	72	No data available		0.03 (−0.62, 0.69)	18
21–40%	0.18 (−0.11, 0.47)	91	0.47 (−0.05, 1.00)‡	30	0.84 (−0.05, 1.74)‡	11
41–60%	0.81 (0.42, 1.20)*	70	0.23 (−0.52, 0.98)	14	2.14 (−1.33, 5.62)	15
≥ 60%	0.03 (−0.66, 0.73)	16	0.21 (−0.14, 0.56)	66	0.56 (−0.24, 1.35)	36
Decrease in training intensity						
Yes	0.08 (−0.34, 0.49)	45	−0.72 (−1.63, 0.19)	10	0.25 (−0.73, 1.24)	8
No	0.28 (0.08, 0.47)*	204	0.37 (0.09, 0.66)*	100	0.68 (0.09, 1.27)†	72
Decrease in training frequency						
Yes	0.35 (−0.36, 1.05)	54	0.16 (−0.17, 0.49)	74	0.95 (−0.48, 2.38)	25
No	0.30 (0.10, 0.50)*	195	0.53 (0.05, 1.01)†	36	0.55 (−0.05, 1.15)‡	55
Duration of the taper						
≤ 7 d	−0.03 (−0.41, 0.35)	54	0.31 (−0.08, 0.70)	52	0.29 (−0.12, 0.70)	47
8–14 d	0.45 (−0.01, 0.90)‡	84	0.58 (0.12, 1.05)*	38	1.59 (−0.01, 3.19)†	33
15–21 d	0.33 (0.00, 0.65)†	75	−0.08 (−0.95, 0.80)	10	No data available	
≥ 22 d	0.39 (−0.08, 0.86)	36	−0.72 (−1.63, 0.19)	10	No data available	
Pattern of the taper						
Step taper	0.10 (−0.65, 0.85)	14	−0.09 (−0.56, 0.38)	36	2.16 (−0.15, 4.47)	25
Progressive taper	0.27 (0.08, 0.45)*	235	0.46 (0.13, 0.80)*	74	0.28 (−0.10, 0.66)‡	55

* $P \leq 0.01$; † $P \leq 0.05$; ‡ $P \leq 0.10$.

Table 2 from Bosquet et al. (2007)

Neary, Martin, and Quinney (2003) evaluated cyclists for 2 tapering protocols against controls. The subjects were trained male cyclists 25 +/- 6 years of age. The training programs were set for four days per week of 60 minutes at 85 – 90 % of maximum heart rate. The taper program for the intense tapering group maintained intensity but reduced the duration progressively down to 20 minutes by the final training day over 7 days. The reduced-intensity group maintained duration but reduced the intensity progressively down to 55 % of maximum heart rate by the final training day over 7 days. The participants were tested for ventilatory thresholds, 40 km time trials, and histochemical analysis of muscles for aerobic and contractile enzymes. A 4.2 % improvement in the time trial of the intense protocol was found versus no improvements in the other cohorts. A 12 % power increase was found in the intense group vs. an 8 % power increase in the duration group. A 14.2 +/- 9.9 % increase in cross sectional area was observed in the type II fibers of the intense training group. No significant changes for type I fibers of either group. Significant increases in succinate dehydrogenase (SDH) were found in type I (11.9 %) and type II fibers (16.2 %) for the intense group and mATPase (15.0 %), cytochrome oxidase (CYTOX) (8.6 %), and beta hydroxyacyl CoA dehydrogenase ([beta]-HOAD) (18.2 %) in type II fibers in the intense group. The reduced intensity group showed significant improvement in cytochrome oxidase (9.5 %) and [beta]-HOAD (17.0 %) in type I fibers and [beta]-HOAD (18.2 %) in type II fibers. Glycogen increases were found for both of the experimental groups but not the control group. The correlation with time trial performance was in the cytochrome oxidase (r^2 = 0.62 – 0.71) and SDH (r^2 = 0.66 – 0.72) for both type I and type II muscle fibers. The results help establish the importance of intensity in eliciting the performance-enhancing changes associated with tapering as well as the possible mechanism involving aerobic enzyme upregulation (41).

Running

In study of British elite runners, Spilsbury, Fudge, Ingham, Faulkner, and Nimmo (2015) retrospectively evaluated characteristics of the athletes' tapering programs. This study used survey data, which was verified with GPS via paired T-tests. Middle distance was identified as 800 to 1,500 m and long distance as 3,000 m steeple chase to 10,000 m. With regular, continuous running training intensity increased for middle distance, long distance, and marathon running during the taper. With interval training, middle distance had higher intensity training while long distance and marathon training had lower intensities during the taper. No direct links to performance were identified with the different strategies within groups (58). This study merely highlighted strategic differences among the elites, which may have roots in experience and historic insight from both the coaches and athletes.

In a study of well-trained distance runners Mujika Goya, Padilla, Grijalba, Gorostiaga, and Ibañez (2000) compared the effects of medium and large volume reductions in training volume. Mean training volume in the overload period leading up to the taper was 669.6 +/- 235.9 km. Low-intensity training for the season before the taper had a mean of 88.0 +/- 7.3 % while of total volume while high-intensity interval training was set at 12.0 +/- 7.3 %. Training programs were set by the athlete's respective coaches. The tests involved 800-meter time trials before and after the tapers. The experiment only defined the volume reduction for the tapers. The experiment involved no manipulation of training intensity. The medium volume taper trial times changed from 125.7 +/- 6.6 to 126.2 +/- 8.0 s. The low volume taper trial times went from 126.1 +/- 4.2 to 124.9 +/- 4.5 s (34). This study did highlight a moderate negative correlation between volume of low-intensity continuous training and change in time trial performance after taper, which may speak to the importance of overall volume reduction to tapering effectiveness. Despite the name of the study, “Physiological responses to a 6-day taper in middle-distance runners: influence of training intensity and volume,” only training volume was an independent variable. No significant performance improvements for the taper were seen and no significant difference between the 2 protocols were observed, owing possibly to the maintenance of rather than an increase in intensity.

Triathlon

Laboratory evidence has demonstrated efficacy for endurance sport tapering when the requisite training cycle conditions are met. Aubrey, Hausswirth, Louis, Coutts, and LE Meur (2014) studied the effects of tapering in the presence and absence of functional overreaching with cycling among triathletes when training intensity was maintained (2). The aforementioned study found that tapering enhanced cycling performance when true overreaching was not present. Subjects were divided into protocols for normal training and functional overreaching. The subjects underwent three weeks of their normal training period, a week of moderate training with reduced duration of 30 % and maintained intensity, an overload period with a 30 % increase in volume or normal training for the controls, and finally a four-week taper period with training duration reduced by 40 %. Maximal incremental cycling performance tests were performed and maximal oxygen uptake was measured at the end of each week of the taper period. The ergometer protocol included a warm up of 15 minutes beginning at 100 watts increasing by 50 watts every 5 minutes. The incremental test increased wattage by 25 every 2 minutes until exhaustion. The control group and the acutely fatigued group showed a respective 81 and 97 % greater chance to show an increase in VO_{2max} than the functional overreaching group. The VO_{2max} ranges for the AF group was identified as 4349 ± 480 vs 4525 ± 407 mL $O_2 \cdot min^{-1}$ and 4517 ± 405 vs 4460 ± 447 mL $O_2 \cdot min^{-1}$. The authors focused on magnitude of differences within and between rather than statistical significance across groups. Given the range of differences no clear expectations of changes in VO_{2max} can be drawn from the observations. The benefits were clear following three weeks of overload training but became unclear across different protocols following the fourth week, reflecting a leveling off of benefits. While the research subjects were triathletes, swim and run performance was absence from the tapering assessment. This study did establish that aerobic capacity could be increased in the taper period when training intensity is maintained.

Evidence from all of the research suggests that training intensity should be overall maintained if not increased. Variations in this general guideline may need to be determined with individual assessment and experimentation.

Frequency Variation

Swimming

Costill, Thomas, Robergs, Pascoe, Lambert, Barr, and Fink. (1991) evaluated training frequency when training consisted of two versus one 1.5 hour sessions. The 24 male collegiate swimmers had all trained together in a single training session for the first 4 weeks. The following 6 weeks had the subjects divided into once versus twice daily training sessions. A subsequent 14 weeks had the subjects all training together once again in the afternoon. Both groups trained 5 days per week. Subjects were tested for creatine kinase, cortisol, and testosterone before, during, and after the overload period. The authors found that a second training bout in 1 day produced no additional performance benefit (8). Sprint performance decreased in the twice daily training group while sprint performance increased in the once daily group. In contrast, swimming power remained relatively unchanged. Tapering greatly alleviated the loss of performance associated with the twice daily program. Maximal sprinting velocity across the whole program improved by 3.7 % with the long group and 3.9 % with the short group. However, 3,000 yard performance was 0.5 % better in the long than the short group on week 11. The format of two training sessions per day might not be applicable to the question of reduced frequency when only 1 session per day is already the training format used by the athlete. When training is reduced to less than once per day questions remain surrounding skill-intensive activities such as swimming independent of fitness measurements. Additionally, Bosquet et al. (2007) found the largest effect size from tapering to be associated with a decrease in frequency (0.35 vs. 0.30). No details on the magnitude of decrease in frequency were discussed in the meta-analysis.

Cycling

Bosquet et al. (2007) found an effect size of 0.95 for reduced training frequency vs. 0.55 for no change in training frequency for cycling tapering. The data presented by the aforementioned do not establish that the frequency difference was the cause of the effect difference. Rather, the effects of other variables such as intensity could explain the effects observed with those studies. The authors of the meta-analysis concluded that it was impossible to measure the true effects of reducing training frequency for this reason. Rietjens, Keizer, Kuipers, and Saris (2001) found that reducing training frequency by 20 % for 21 days still maintained VO_{2max} and maximal workload in well-trained male cyclists (50). However, this study did not assess race performance, which is not in lockstep with measured physiologic variables. So far the evidence on cycling training frequency during tapering most consistently shows that maintaining frequency at least 80 % from the overload period was most effective.

Running

Some evidence suggests that aerobic fitness can be maintained in runners when frequency is reduced and substituted with cross training (24). Houmard, Scott, Justice, and Chenier (1994) found that a taper period of high-intensity running intervals over 7 days improved five km run performance whereas cycling for 7 days maintained 5 km run performance (24). The subjects were male and female distance runners who trained at least 48 km per week over the past 2 years. Intervals, fartlek, and racing comprised 6 to 10 % of training activity over that time frame. Testing included a 5 km time trial on Day 1 followed by maximal voluntary isometric force on a dynamometer, a submaximal run for running economy, and a maximal run for time to exhaustion on Day 2. Time trial performance in the run group improved by 2.8 +/- 0.4 % whereas there were no significant changes in the cycle or control groups. Day 2 trials likewise showed significant changes only in the run taper group, except for peak isometric forces, which showed no significant changes with any group. Submaximal running economy improved by 7 %, submaximal speed by 2 %, and time to exhaustion by 4 % in the run taper group. Mujika, Goya, Ruiz, Grijalba, Santisteban, and Padilla (2002) evaluated the influence of training frequency on the taper period in a cohort of highly trained middle-distance runners (35). The taper protocols were progressive, nonlinear patterns descending from 55 to 20 % of pre-taper distances, consisting of high-intensity interval training. The difference between the 2 experimental protocols was that the moderate frequency consisted of a break from training on Days 3 and 6 of the taper, whereas the high frequency protocols had training every day of the taper. The subjects were tested with a time trial distance was 800 meters performed 7 days apart before and after the taper. The results that followed showed only significant improvements in the subjects that took no days off (124.2 +/- 4.9 s to 121.8 +/- 4.7 s) whereas the other cohort showed non-significant improvements (127.1 +/- 2.1 to 126.6 +/- 2.8 s). Of note Mujika et al. used a cohort that maintained a proportion of low-intensity continuous training at

78.2 +/- 3.2 % while high-intensity interval training was at 21.8 +/- 3.2 % in the 3 weeks prior to the taper. In a survey of British elite runners, Spilsbury et al. (2015) found that training frequencies decreased in continuous running and no changes in interval training in the taper period (58). Decreases in training frequency in the taper period were correlated with higher training frequency in the overload period. However, as the data was presented as medians with relatively wide interquartile ranges, the interpretation of athlete training frequency central tendencies is ambiguous. It is possible that the implemented training strategies were highly individualized and created in collaboration with coaches who may have adjusted them from season to season. Further, there was no direct correlation with performance across the different tapering strategies. This study only looked at the practices of elite athletes. No benefit from reduced training frequency was elucidated by the Spilsbury study (58). The review by Bosquet et. Al (2007) found a statistically significant effect size difference of 0.53 for maintained for vs. 0.16 for reduced frequency.

Considering that training frequency of sub disciplines with triathletes is generally lower than with their single-discipline counterparts, it can be expected that maintaining frequency as much as possible while accommodating any inevitable days off from training. If the elite runners are any indication, reducing training frequency may be a function of training frequency during the overload period for triathletes. Ostensibly if a day off is necessary, then the higher frequency sub disciplines should be what is cut. Exact strategies may be determined from experimentation with time trials and low-priority races.

Duration of Taper Period

Swimming

For swimming Bosquet et al. (2007) found an effect size of -0.03 for 7 days or less, 0.45 for 8 to 14 days, 0.33 for 15 to 21 days, and 0.39 for a duration of 22 or more days. These effect values make no distinction between different competitive strokes nor distance. No further research details for taper duration were available from the meta-analysis. Research with significant biomechanical and performance changes had taper periods up to three weeks for eliciting improvements in maximal muscle power, type IIA fiber cross sectional area, and muscle fiber shortening velocity (7,28,67,68,69,71,72). Duration of taper was not the independent variable in any of the swimming studies reviewed herein.

Cycling

The studies reviewed for cycling had taper durations in the range of 7 to 21 days. Objectives ranged from evaluating maintaining to enhancing performance. Bosquet et al. (2007) found an effect size of 0.29 for a taper duration of seven days or less and an effect size of 1.59 for 8 to 14 days for 6 studies. No data for tapering periods longer than 14 days was available nor were any details for the studies comprising the meta-analysis. Rietjens et al. (2001), one of the above review's citations, found that cycling maximal power and VO2max could be maintained for a full 21 days with reduced training load both in intensity and duration (50). The aforementioned used cohorts with a continuous training program and an intermittent training program with intervals. The training volume in this study was reduced by 50 % in both protocols. However, the measurements were VO_{2max} and maximal workload rather than race performance. The duration over which performance measures can be maintained may be an important consideration in the world the athlete juggling multiple responsibilities before embarking on trip to a distant race site with all of the incumbent logistics. Neary et al. (1992) used taper duration as an independent variable, which was set at 4 vs. 8 days against a non-training control cohort and a non-tapering cohort (42). Testing consisted of a 60-minute submaximal test for power output, an incremental ergometer test for ventilatory threshold, and muscle biopsy for histochemical aerobic enzymatic, glycogen, and protein analysis. Enzymes of analysis included carnitine palmityltransferase, citrate synthase, beta hydroxyacyl CoA dehydrogenase, cytochrome oxidase, and lactate dehydrogenase (LDH). All values were significantly increased except for LDH for the taper groups, with no significant differences seen between the two groups. The nonsignificant decrease in LDH could reflect a decrease in hemolysis or muscle damage. At the very least the evidence shows that a taper duration of up to two 2 is safe for performance.

Running

Bosquet et al. (2007) identified an effect size of 0.58 for 8 – 14 days vs. 0.31 for <= 7 days. Of note the studies reviewed mostly focused on middle distance running.

Spilsbury et al. (2015) found that tapering duration correlated positively with the race distance in a survey of elite runners (R = 0.63). Middle distance was identified as 800 to 1,500 m and long distance as 3,000 m steeple chase to 10,000 m. In this study the median durations for tapering were six days for middle distance, 6 days for long distance, and 14 days for marathon runners. The interval volume reductions were 53 % for middle distance, 67 % for long distance, and 64 % for marathon distance. The authors noted that taper duration also correlated with the percentage of race pace for regular training. No direct links to performance were noted, as this was not an experiment. The research evaluated for running did not use taper duration as an independent variable.

What insight of the above can be applied to triathlon may be speculative, but the data from runners suggests is that experience may be an important basis setting the duration parameter of the tapering period. Further, taper during may be a function of race distance. Two weeks appears to be a safe starting point when in doubt. Experimentation with time trials or low-priority races may adjust the plan accordingly leading into high-priority races.

Taper Pattern

Swimming

Bosquet et al. (2007) found an effect size of 0.10 for a step taper vs. 0.27 for a progressive taper based on 8 studies. The studies were not specifically identified in the listed references for the aforementioned meta-analysis. In all of the articles reviewed herein, none specifically had the taper pattern as the independent variable for direct observations. In contrast, some computer modeling was used to evaluate the effectiveness of different possible taper patterns, which is beyond the scope of this review.

Cycling

Bosquet et al. (2007) found an effect size of 2.16 with a step taper vs. 0.26 with a progressive. Again, details were not available to clarify what the differences in tapering strategies were within progressive tapering. No direct observations among the studies in the meta-analyses nor in this review directly compared tapering patterns. The individual prospective studies reviewed that found race or time trial performance enhancement in cycling used a progressive taper.

Running

Bosquet et al. (2007) found an effect size of -0.09 associated with a step taper vs. 0.45 for a progressive taper. The same limitation for the swimming and cycling from the aforementioned meta-analysis apply to running. Studies reviewed did not specifically compare different tapering patterns for running. The studies performed by Mujika et al. used fast exponential patterns over six days to produce their robust findings of enhanced performance, as discussed elsewhere in this review (34,35).

Triathlon

So far laboratory protocols for triathlon tapering have centered on the land-based portion of standard triathlons. These controlled studies have found that exponential tapering is more effective than step-wise tapering for cycling and running components of triathlon. Bannister et al. (1999) found most significant improvements in cycle ergometry following an exponential taper as opposed to a step-reduction taper. A non-significant improvement in 5 km run time was also recorded in the subjects (3). Additionally, the aforementioned study found that a fast, exponential taper resulted in better performance in maximal cycle ergometry than a slow exponential taper. Initially the comparison was between a single mean step reduction taper to an exponential taper pattern (tau = 5). The exponential group reduced their training volume by 31 % over the period while the step group reduced their training volume by 22 %. Following the above experiment, the athletes resumed heavy training and were subsequently divided into a slow (tau = 8) exponential group (50 % reduction) and a fast (tau = 4) exponential group (65 % reduction). The ergometer test was an incremental increase in wattage every minute by 30 W while attempting to maintain 80 rpm. According to this model, an important component the effectiveness of the pattern is that it follows a standard square wave of a training stimulus (i.e. training load held constant) for 28 days. In Taper 1 the step taper cohort improved by 1.3 % on in the run time in the first week then increased slightly after the second week while the power by 1.5 % after two weeks. The exponential taper run time improved by 1.1 % after the first week and 4.0 % after the second week while the power increased by 5.4 % after two weeks. In Taper 2, run performance improved by 1.5 % after Week 1 and 2.4 % after Week 2 and power increased 2.8 % after Week 1 and 3.8 % after Week 2 in the slow exponential taper. In the fast exponential taper run performance increased by 3.5 % after Week 1 and 6.3 % after Week 2 and power increased 1.6 % after week 1 and 7.9 % after week 2. In both taper comparisons, only the power increase was considered a significant difference between the respective protocols. In Taper 2 VO_{2max} improved 7.2 % after the first week and 9.1 % after week 2. Lactate threshold increased 2.8 % of VO_{2max} the first week and 5.6 % of VO_{2max} by the end of Week 2. The values were from an unspecified cohort of eight subjects who remained after the end of Taper 2. The aerobic capacity changes after both weeks and the threshold change after Week 2 were deemed significant increases. The authors noted that their metabolic findings were a departure from the research VO_{2max} and tapering published previously.

Zarkadas Carter, and Banister (1995), discussed below, evaluated tapering protocols in Ironman triathletes. The authors concluded that an exponential taper resulted in a 4 % improvement in run time trial performance and a 5 % improvement in cycling ergometer maximal ramp power, while no significant improvement was found with a step-reduction taper (78). The subjects were triathletes engaging in tapering following a 3-month training period. A second exponential taper period for a high and a low volume group following another 3-month training period resulted in a respective 6 % and 2 % improvements in run time while maximal ramp time increased significantly by 8 % in the low volume group.

Overall, the evidence suggests that a progressive taper pattern is most efficacious. The triathlon-specific research reviewed here indicates that a fast, exponential taper produces superior results to other tapering pattern. While this specific research questions may remain surrounding the effects of this pattern on swim perform, the aforementioned tapering pattern appears to be the most promising. Individuals may experiment to further customize an appropriate strategy.

Overall Training Load Effects on Taper

As volume of training varies widely across athletes, questions surround how this variable affects the importance and effects of tapering. The studies reviewed here consistently concluded that the overload period is tantamount to the effectiveness of tapering. However, they have not recommended an absolute duration of the taper corresponding to training load nor a precise magnitude of load reduction. Variations of characteristics in the overload period such as the magnitude of the overload may shape tapering needs.

In a computer-simulated model, Thomas, Mujika, and Busso (2009) attempted to differentiate effects of tapering on non-athletes vs. athletes in both a two-phase and linear tapers following a 28 day overload with a 20 % training volume increase (64). While the authors concluded there was no significant difference in benefits of the taper, the two cohorts had different exercise protocols and both used linear progressive tapers of both 1 and 2-phase formats. The athletes had a swim protocol and the non-athletes had a cycling ergometer protocol. Each cohort had different levels of training load reductions and taper durations deemed as optimal for the two tapering strategies (64). Further research may be needed to clarify the most effective variation.

What the research has concluded to date is that the overload period of training is important to eliciting the benefit of tapering. Research and theoretical models have pointed to the accumulation of fatigue being tantamount to the performance benefits associated with tapering. The important characteristics, such as undulation vs. square wave load, of prior training volume to tapering strategies will need to be further clarified to propose an optimal model for tapering.

Importance of Overload Training Period

Thomas, Mujika, and Busso (2008) showed that optimization of tapering in swimming required an overload period prior to the taper using a mathematical model (63). However, the effect of tapering on triathlon-specific swimming has not been intensively studied. Complicating the study of triathlon swim tapering is that triathlon swimming may be submaximal and represents a minor portion of the total distance covered in the race. Wu, Peiffer, Peeling, Brisswalter, Lau, Nosaka, and Abbiss (2016) found that a positive swim split enhances sprint triathlon finishing times over negative and even split pacing strategies (77). In contrast, pure swimming may be fastest with a negative split as there is no need to conserve energy for subsequent legs of the race (40). Thus given the differences in pacing of swimming for triathlons, the accumulation of fatigue, tantamount to tapering theories, and the optimal training load may differ between pure swimming and triathlon swimming and may raise questions about optimal tapering strategies. The role of the overload period in relation to the effectiveness of tapering to cycling performance was highlighted by Aubrey et al. (2014). The authors found that a three week overload period with a volume increase of 30 % over the baseline led to a 68 % chance of greater VO_{2max} improvements over controls in maximum incremental cycling following tapering when functional overreaching was not present (2). Benefits were less clear when functional overreaching was present in the participants. These performance changes occurred in the first two of a four-week tapering period. However, this study has a step taper design for the tapering period, which has been found to be inferior to progressive tapering, as discussed elsewhere. The research reviewed has consistently shown that the overload period is tantamount to the performance enhancement with tapering. The role of the overload period and tapering strategies for triathlon swimming can at this time best be extrapolated from research on swimming training, training in other disciplines, and triathlon research focusing on the other disciplines.

Fitness and Physiologic Effects Measurements in Triathlon and Sub Disciplines

Overall the evidence on aerobic capacity from tapering has been mixed. Aubrey et al. (2014) found a significantly increased VO_{2max} following a taper when an overload was present. Zarkadas et al. (1995) fund a significant increase in anaerobic threshold improvement of 5.6 % and a significant increase in VO_{2max} of 9.53 % among triathletes following a 13-day exponential taper (78). Likewise, Banister et al. (1999) found significant increases in VO_{2max} following both 1 and 2 weeks of tapering in trained triathletes (2). Other research has not shown a change in VO_{2max} following tapering, owing possibly to study design (23,37,56).

Some blood variables of interest to oxygen delivery in triathletes include red blood cell count, hemoglobin, and hematocrit. Mujika, Padilla, Geyssant, and Chatard (1998) evaluated responsiveness to tapering in red blood cell count, hemoglobin, and hematocrit in competitive swimmers before and after the taper as well as performance (36). A significant correlation was found between post taper red cell count and performance, but only mean corpuscular hemoglobin and mean corpuscular hemoglobin concentration were found to change significantly over a four-week taper. Raw performance improvement with tapering improved by 2.32 +/- 1.69 %. Shepley, MacDougall, Cipriano, Sutton, Tarnopolsky, and Coates (1992) observed a significant increase in total blood volume and red cell volume following high-intensity tapering in runners with concomitant 22 % improvement in time to exhaustion on a treadmill (56).

The subjects were highly trained intercollegiate cross country athletes who underwent and eight-week overload period followed by a seven day taper period during the 5 months between the cross country and track season. The article left it unclear which portion of the intersession the study encompassed nor how the time between the cross country and study was spent. Similarly, some studies have shown an increase in hemoglobin and hematocrit following tapering in swimmers, possible due to decreased hemolysis (36). Other possible explanations for increased hematocrit following tapering among swimmers include either an increase in erythropoiesis, reduced plasma volume, or reduced acidosis, positively affecting mean corpuscular volume (53). Likewise, some evidence has shown decreased haptoglobin following hard swim training unlike following the taper, which indicates increased hemolysis from hard training that was curtailed by tapering. Also, newer cells may have higher mean corpuscular volumes, which will intrinsically result in higher hematocrits (36). Hemolysis during training can be either exertional or impact-related, which can be expected to be reduced in a tapering program with reduced training volume provided increased intensity does not nullify the reduction (47). Reduced hemolysis with concomitant increased red blood cell mass may lead to better oxygen-carrying capacity.(47) In a study focusing on middle distance runners, Mujika et al. (2002) observed increased erythropoiesis following tapering, as indicated by increased reticulocytes.(35) Based on the research of related subdisciplines, we can postulate a similar outcome from a triathlon taper following a substantial overload period. These changes are something to consider as a component goal of tapering despite while the athlete may be asymptomatic.

Other factors affecting oxygen utilization after tapering include changes in the muscle fibers that may enhance VO_{2max}. Neary et al. (1992 and 2003) found that tapering increases aerobic enzyme activity in Type I muscle fibers in cyclists.(41,42) In this study, the taper protocols were of four and eight day durations and matched against a non-tapering group and a control group without training. Contrary to the above findings, Shepley et al (1985) found no effect on VO_{2max} from tapering in cross-country and middle-distance runners (56). The aforementioned study implemented an overload period for eight weeks with six training days per week. The participants then were subject to a series of three seven-day taper protocols interspersed with four weeks of regular training. The taper protocols included high-intensity intervals over five training days for the high-intensity taper and two days without training, a low-intensity taper at 57 – 60 % VO_{2max}, and a rest only taper. The design involved repeat measures and randomly assigned sequences of tapering formats. Because the high-intensity taper was not progressive, the format was somewhat outside the body of evidence for tapering patterns. While evidence has been somewhat varied from study to study due to study designs and possibly other limitations, research has most consistently shown enhanced finishing times rather than enhanced aerobic capacity following tapering (56).

Effects on Power Output and Economy

Tapering has been shown to enhance power and finishing times in collegiate swimmers (9). Trappe et al. (2006) found an 18 % increase in power in type IIA fibers among novice marathon trainees following taper. The subjects were all recreationally active prior to the 13-week build period and three-week taper, which was ambiguous as to whether it was a multistep reduction taper or progressive taper. The aforementioned power increase was all relative to size, as no significant increase in CSA was found in the fibers following the taper. The training involved in the above study did not specify higher intensities in the taper that would be expected to more directly target type II fibers nor was strength training involved. Type II fibers play a role in strength and elastic recoil and can thereby enhance economy and efficiency (35). In other research, tapering has been shown to increase muscle cross sectional area in Type IIa fibers as well as power (Trappe, Costill, and Thomas 2000, 2001) in swimming and cycling (67,68). Trappe et al. implemented a 21-day high-intensity tapering program in highly-trained, collegiate swimmers. The aforementioned found the tapering in program to expand Type IIa cross sectional area by 11 % and improve power by 2.5 fold (67). In turn, performance improved by 4 % in their respective specialty strokes. Likewise, similar improvements have been found in runners following a taper. Luden et al. (1985) found muscle cross sectional area increased by 7 %, a peak force increase by 11 %, absolute power increase by 9 %, and a performance improvement by 3 % following a three week taper in male collegiate cross country runners (30). In this study the subjects performed an eight-kilometer time trial before and after a four-week taper down to 50 % of mid-season volume. Similarly, Neary et al. (2003) found a Type II CSA increase of 14.2 +/- 9.9 % following a taper in cyclists who maintained training intensity but progressively reduced duration over a seven-day taper. This was accompanied by a 12 % power increase in the intensified taper group vs. 8 % in the duration group (41). While undoubtedly the aforementioned biopsy and power data are applicable to triathlon, the practical implications remain to be clarified as the sub disciplines may have less training frequency than the single disciplines and interactions across all sub disciplines are not well-established. However, the case for a progressive, intensified taper appears to be consistent for increasing power output.

Effects of Tapering on Psychological State/Mood

A number of studies have evaluated how training and tapering affects the mental states of athletes (37). The literature on training, tapering, and psychological state have broadly categorized mood disturbances, mental function, and sleep disturbances under the aegis of psychology for analytical purposes (9,19-22,33,54,62,74). Key research questions therein address the role of psychological enhancement on athletic performance, the utility of psychometric assessments for monitoring effectiveness and progress of tapering, and the athlete readiness to perform at his or her best. The impact of training and tapering on psychological states have been evaluated with psychometric questionnaires. Some of the more common tools used include the Profile of Mood States (POMS), Recovery Stress Questionnaire for Athletes (RESTQ-S), Daily Analysis of Life Demands of Athletes (DALDA), the overtraining questionnaire of Societe Francaise de Medecine du Sport (SFMS), State Trait Anxiety Inventory (STAI), Perceived Stress Scale (PSS), Multi-Component Training Distress Scale (MTDS), Competitive State Anxiety Inventory-2, Derogatis Symptom Checklist (DSS), State Anxiety Personality, and the Mood Questionnaire (62). As the broader subject of sport psychology is beyond the scope of the review, some important points will be highlighted with the discussion of the articles below.

Some authors have proposed that a positive mood state is a direct cause of athletic performance enhancement (37). On the other hand, some authors have suggested that psychological enhancement from tapering was a result of tapering that can be used to monitor tapering progress (57,60,62,63,64). To explore the connection between psychological state and athletic performance, some research has focused on psychological changes associated with functional overreaching and tapering thereby illustrating an extreme scenario (53). While tapering has not required prior functional overreaching to be effective, overreaching remains relevant to this area of research as tapering is an important remedy.

Psychological Effects of Training

The relationship between training stress and anxiety was explored by Millet, Groslambert, Barbier, Rouillon, and Candau (2005) using the State Trait Anxiety Inventory (33). This model explored both somatic effects (i.e. physical symptoms) and cognitive anxiety (i.e. mental components). The subjects in this study were four professional triathletes. The highest levels of anxiety were found to be at periods of illness for a subset of athletes, following an altitude camp, and immediately preceding the International Triathlon Union Long Course Championship. A moderate correlation between the two ($r = 0.32$) was identified. However, confounding factors impacting anxiety including competition were identified as limitations to the findings. While this study was not evaluating tapering effects per se, a triathlon distance of 4 km swimming, 120 km of cycling, and 30 km of running would be expected to have a relatively long taper period included in the training plan to be in concordance with the literature and coaching opinions discussed elsewhere in this review. The duration of the taper could span up to 35 days as discussed previously. However, the taper duration in this study was less than 1 week as might be expected of professional triathletes. In any event, this study does relate training loads to anxiety, hence its relevance to psychological benefits of tapering. However, the above research does not clarify the optimal level of arousal for the athlete in relation to manipulating athlete mental states. Therefore, cautious interpretation may be needed in looking for changes in psychological states between the training overload periods and the ends of the taper periods.

Link Between Mood and Athletic Performance

The research by Hooper, Mackinnon, Howard, Gordon, and Bachmann (1995) found that psychometric markers predicted performance (22). This study evaluated the relationship between staleness and several psychometric and physiologic measurements. Staleness in this context was identified when the conditions of failure to improve throughout the season, despite the absence of illness, and a fatigue rating of greater than 5 on a rating scale of 1 to 7. Subjects were 14 elite swimmers (ages 17.4 +/- 1.5 years). Training consisted of 6 months of 10 to 12 workouts per week with Sunday off from structured training. The taper period was 2 to 3 weeks of progressive volume reduction (49 to 95 %) according to the program set forth by their respective coaches. Only 3 subjects, all female, were identified as stale. Symptoms surrounding overtraining have been referred to as “staleness” and “burnout,” as discussed in the article, accounting for 76 % of the variance during the overload period and 72 % of the variance in the race performance following the taper period. Psychometric markers for staleness were recorded in the athletes' journals, including sleep and distress. Other subjective variables included soreness and fatigue. Epinephrine in turn predicted 85 % of the variance for staleness.

In a review of tapering effects by Mujika et al. (2004) retrospectively identified enhanced psychological states as being in part as directly responsible for enhanced athletic performance (37). The psychometric test under study was the POMS and the Recovery Stress Questionnaire. The aforementioned review's sources had mixed results, indicating unreliable performance prediction from POMS. In the 18 studies reported on by Mujika et al. (2004), 9 out of the 11 that reported on mood state and performance showed that either both increased with tapering or the results were mixed. Further research may clarify the connections between mood, tapering, and triathlon performance. In the meantime, mood enhancement can be a tentative objective of the tapering period.

Protocols with Multiple Metrics for Predicting Performance

Hooper, Mackinnon, and Ginn (1998) evaluated several tapering protocols for swimmers training for a state championship (19). The overload period involved 4 weeks of 40 km per week and 150 minutes of dryland workouts over 8 workouts per week. Workout intensities were scaled from 1 to 7. The in-water workouts maintained an intensity of 5 for 80 % of the workouts. The dryland portion maintained an average intensity rating of 5. Three different tapering protocols were implemented. Method A involved continuing the workouts of the overload period but adjusting frequency, unbeknownst to the athletes, based on the psychometric and subjective physiologic variables of sleep, fatigue, stress, and muscle soreness. Method B involved a progressive taper of 10 % volume reductions per day while maintaining frequency and intensity. Method C involved reducing the duration as in B but also reducing the intensity by 10 % until the last day of the taper training was completely easy. The performance tests consisted of 100 and 400 meter time trials. All of the methods showed significant improvement in tension and depression and two showed significant improvement in anger after 2 weeks. None of the protocols showed significant improvements in performance. The authors speculated that the lack of significant improvements reflect the discordance between the time trials and the race distances actually trained for, which were unspecified. Additionally, all of the training intensities were rated as high, which is not necessarily physiologically appropriate as previous research indicates that elite athletes predominantly train at lower intensities (65). The volume reduction method was continuously progressive rather than exponential, which may have impacted effectiveness.

In a subsequent study Hooper, Mackinnon, and Howard (1999) evaluated the relationship of several biochemical and physiologic variables and POMS with swimming performance in elite Australian swimmers (21). The variables norepinephrine, heart rate following maximal exercise, and level of confusion from the profile of mood state together comprised components of a polynomial equation that predicted changes in swimming performance ($r^2 = 0.98$) following tapering. No POMS variables alone predicted performance. In this study the swimmers performed their specialty strokes in the tests, hence a stronger predictive power of the POMS for enhanced performance than that observed with time trials in other studies.

Coutts, Wallace, and Slattery (2007) evaluated the recovery states of triathletes based on mental and physiologic metrics (9). RESTQ-76 and a number of biochemical assays were used to evaluate the athletes. The athletes were grouped into two different protocols of normal training (NT) and intensified training (IT) programs, encompassing all of the subdisciplines. The training programs spanned four weeks of the base training period followed by a 2-week progressive taper. The subjects completed a three-kilometer time trial at the end of each week of the protocol. The RESTQ-76 results for the groups showed a significant decrease in psychometric scores for the IT group compared to the NT group during the overload period. However, during the taper period, strong score increases in the taper period were observed in the IT group compared to the NT group. In turn the IT group experienced a decrease in performance in the time trials during the overload period compared to the NT group. The IT group performance equaled the NT group performance by the end of the taper period. It is noteworthy that the athletic performance was measured in running time trials rather than actual races. Real world conditions might evoke different psychological conditions directly related to the race. External validity could be questioned with the differences in psychological underpinnings of the time trial conditions vs. the novelty of a triathlon race course.

Sleep

Slow wave sleep (SWS) has an important variable in sleep studies and training. SWS is regarded as an important non-REM component of recovery from training. In theory the proportion of sleep represented by SWS is proportional to the body's needed amount of recovery from training (62). Taylor, Rogers, and Driver (1997) studied polysomnography in elite female swimmers over an initial period, following an overload period, and following a taper period (62). The SWS comprised 26, 31, and 16% of the total sleep for the beginning, overload, and taper periods respectively. In this study the POMS results most positively correlated with the overload period. No changes in sleep disturbances were noted. This study did not suggest that changes in sleep proportionately enhanced athletic performance, but rather indirectly showed the relationship of sleep patterns and training loads. In turn, research by Aubry et al. (2014) found that functional overreaching caused sleep problems, which were reversed by tapering (2). Overall the research shows that slow wave sleep is a function of training recovery needs, which varies with the phases of the training cycle.

Assessments for Monitoring Recovery and Adjusting Tapering

Key questions as to the psychological impact of tapering concern the use of assessments therein for prescribing, adjusting, and monitoring tapering has been addressed with some reviews. In a review of psychological impact and assessment of physical training, Saw, Main, and Gastin (2016) evaluated subjective vs. objective methods of monitoring training responses (54). This review encompassed a total of 64 original research articles. A number of objective and subjective measures were assessed, including immune and muscle damage blood biomarkers as well as physiologic metrics. The subjective values were loosely scaled and matched against both performance and physiologic metrics. The result was that subjective methods were overall more efficacious and practical than objective measures for assessing athlete training responses. Acute training monitoring variables found to be useful included irritability, willingness to train, and enjoyment of training. In turn psychometric variables found to be most useful for monitoring chronic training included conflict/pressure, self-regulation, lack of energy. While not a review of tapering per se, this review does help solidify the link between performance and psychological state, which is the crux of the concomitant benefit from tapering.

While much of the focus of the role of psychological states has been on the moments in between training, a question directly related to performance surrounds the relationship between rate of perceived exertion (RPE) and physiologic function. The connection between RPE and training intensity has been investigated with mixed results. In the review compiled by Mujika et al. (2004) only the study measuring RPE with VO_{2max} in swimming found a decreased average RPE at 90 % VO_{2max} following tapering (37). The cited studies utilizing running found no changes in RPE relative to VO_2 following tapering. In contrast, all of the studies evaluating the impact of tapering on heart rate (HR) in relation to RPE have been more consistently linked the change to cycling performance. A strong relationship between the lactate to RPE ratio and fatigue was also identified in one study of cyclists. Two weeks of tapering following an overload period resulted in a reduced blood lactate to RPE ratio. However, no performance changes were recorded in the aforementioned study.

The studies reviewed reveal mixed results of the impact of tapering on psychological state but most consistently that tapering was efficacious for athletic performance. Tapering and psychometric measurements most consistently correlated with performance in the events the athletes were actually training for. The research reviewed did not directly confirm performance enhancement stemming directly from psychological improvements. However, the practical implications suggest that psychometric assessment may be useful in evaluating the effectiveness of tapering and alleviating staleness with adjustments to training. It may ultimately be up to the coach and the athlete to identify confounding factors that impact psychological state and enlist more comprehensive sports psychology services to enhance athlete mental readiness.

Inter-Workout Recovery Methods

In order to identify and extrapolate the most effective recovery methods between workouts during the tapering periods leading up to a race, the study of the acute phase between repeat bouts of exercise may yield insight. There remains no consensus among the coaches as the best methods of recovery and no clear guidelines on rest vs. recovery in the scientific literature reviewed herein. In a review of training recovery, Bishop, Jones, and Woods (2008) discussed the ambiguity of active vs. passive recovery from a 5 km race as studied by Bosak et al. (5). This study found no central tendency difference between active vs. passive recovery. However, some individuals seemed to recover best with 1 particular method. Hinzpeter , Zamorano, Cuzmar, Lopez, and Burboa (2014) found 20-minute training intervals at 60 % maximal intensity to be superior to passive recovery following repeat bouts of high-intensity 200 meter race intervals in 25 competitive swimmers ages 15 to 19 (18). The enhancement of active recovery was evidenced by drops of 68 % of peak lactate load vs. a 20 % drop in the passive recovery group. Nonetheless, the case for alternate methods of recovery from repeat bouts of high-intensity training may not be indicative of how days between high-intensity training days should be spent to optimize recovery. Marquet, Hausswirth, Hays, Vettoretti, and Brisswalter (2014) found submersion in ice baths to be more effective than passive and active recovery practices in preparing for the next segment of competition in BMX pilots (31). While the aforementioned recovery practices may be applicable to short-duration competition, training for longer duration competitions may be separated by hours if not days. Optimal training intensity between bouts of high-intensity endurance training such as in triathlon is not well-established by existing evidence. However, recovery advice is still given in lay books. In Lore of Running, Tim Noakes advised complete rest with substantial sedentary time in the day preceding an ultradistance race (43). Regardless of whether complete rest is conducive to optimal performance in otherwise healthy runners, the importance of complete rest in multidisciplinary events and low-impact activities remains to be clarified. While some coaches may prescribe complete rest, published evidence to date has been somewhat mixed regarding days without training for enhancing athletic performance. Further complicating the ambiguities is absence of details on how non-training days were spent. Specifically, "rest" and "complete rest" remain undefined in the scientific literature reviewed herein. To understand the possible metabolic impact on athletic performance of inactive periods, one can turn to the evidence of health impact from sedentary behavior. Research has consistently shown excessive sitting to have adverse effects on health, including increased mortality risk (10,32,59,62). Adverse neurologic effects of prolonged sitting have also been identified. Decreased sensitivity to insulin has been observed from only one day of sedentary inactivity (10,32,59,62). Stephens, Granados, Zderic, Hamilton, and Braun (2011) studied the effect of prolonged sitting with and without caloric adjustments on healthy, fit, non-obese subjects (59). The authors found that one day of prolonged sitting attenuated the insulin response in healthy, recreationally active individuals even when calories were adjusted for activity level. While the authors did note that this may not be generalizable to highly trained individuals, it does highlight the importance of considering how days should be spent in the absence of structured training. Considering the importance of insulin to human performance and health, concrete guidelines on passive vs. alternate methods of recovery may be necessary to optimize race performance.   Exercise may have other benefits in addition to directly elevating fitness. Light exercise may enhance the recovery process (66). The effect of the additional circulating blood, with concomitant tissue perfusion, from light exercise and activity is not yet well-established. The potential metabolic effect of prolonged sedentary behavior during taper on performance has not been clearly evaluated. Protein synthesis has been found to be enhanced with 45 minutes of walking at 40 % VO_{2peak} (55). The potential metabolic effect, of complete sedentary inactivity during taper, on performance has not been clearly evaluated. Studies performed to date identify absence of training without further details of activities the corresponding days (6,24,34,35,58,65). Studies performed to date only identify absence of training but not further details of the corresponding days. More precise details and effect of complete rest during taper may need to be evaluated further before "complete rest" can be recommended as efficacious for tapering. While most of this research has focused on relatively healthy, able-bodied subjects, the needs of individuals need consideration to promote performance gains from training. In clinical cases, "complete rest" has been advised for progressive running training in obese individuals when the alternative is running (44). For the trained athlete, following the guidelines of reducing training by no more than 20 % may serve a general guideline for structed practices. Beyond training regimens, athletes may need to follow their coaches' advice and address their individual needs while monitoring any applicable symptoms.

In addition to physiologic benefits, training during tapering may tie directly into skill development. For example, light swimming may provide opportunities to practice technical aspects such as sighting and any drills addressing deficits with forward propulsion. Joe Friel identifies one cycling skill objective as continuous pedaling without shifting from side to side in order to maintain speed. More specific skills to the race named by Friel include cornering skills. Specific cornering skills as identified include leaning, countersteering, and steering pertaining to direction of turns and road conditions. If the athlete is onsite near the race venue there may be opportunity to practice and anticipate responses on the actual course. As for running, Friel identifies posture and foot striking surface as skill areas conducive to running performance. Like cycling, being on site during the taper period may afford opportunity to practice on the specific terrain (46). In any event, skill reinforcement has been outside the scope of research on tapering. While science may not find physiologic benefits from maintaining training frequency of 100 % during the taper period, science cannot completely supersede the judgement of the athletes and coaches and skill practice may need to be implemented in the taper period.

Tapering of High-Level Athletes

Insight into practices of elites from other endurance disciplines may yield some insight into formulaic practices for success. In a study of Olympic and world championship gold medal cross country skiers and biathletes, Tonnessen et al. (2014) found only 27 % of subjects took a rest day in the final 5 days of taper before competition (65). Thus, daily training of some level need not be seen as a barrier to athletic performance and coaches should have sufficient insight into the athletes' needs before a top priority competition. As discussed previously, Mujika et al. (2000, 2002) showed that 6-day tapers without rest were more effective for performance enhancement than a taper with 2 rest days among high-level cross country runners (34,35).

Considering the benefits of exercise and the ambiguity surrounding non-training, it would be beneficial to coaches and athletes to have clarity on the value of "active recovery" versus "passive recovery" during the taper period as well as insight into optimal durations and intensity in order to maximize performance on race day. As research findings have been very method-dependent, the coaches had best stay the course of continuous assessment of the athlete and deviate only gradually from the athlete's established training formulas for success. Coaches can make incremental adjustments based on scientific research as evidence for training methods emerges.

Pre-Race Tests for Effectiveness of Taper

Attempts have been to correlate non-invasive physiologic measurements of recovery with post-taper race performance. Hug, Heyer, Naef, Buchheit, Wehrlin, and Millet (2014) found a significant correlation between marathon performance improvements and decrease in heart rate recovery following 2 weeks of tapering. In this study overload period increased the usual volume by 23 +/- 10 % (27). The athletes proceeded with four weeks of their usual training program and then entered an overload period in which an additional 1 hour high-intensity session per week was added and the long run duration was increased by 30 minutes. The tapering period has 1 fewer workout per week, the number of high-intensity sessions continued, and an overall training load reduction of 33 +/- 7 % (see figure below).

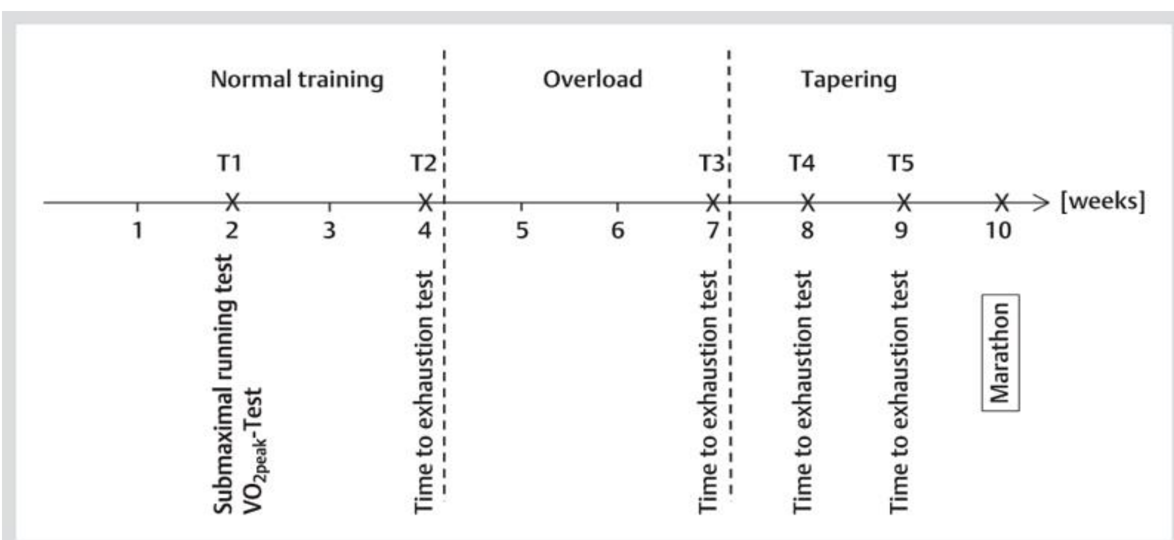


Fig. 1 Study design. Testing at time point T1 was composed of a "submaximal running test" and a $V˙O_{2peak}$ test. At T2, T3, T4 and T5, the athletes performed an identical "Time to exhaustion test" as well as heart rate recovery (HRR) and heart rate variability (HRV) assessment.

Figure 1 from Hugh et al. (2014)

Parasympathetic reactivation in the above study was significantly different between the final week of the overload period and the end of the second week of the taper period. Below, changes in parasympathetic activity with root mean square of successive differences in times between heartbeats (27).

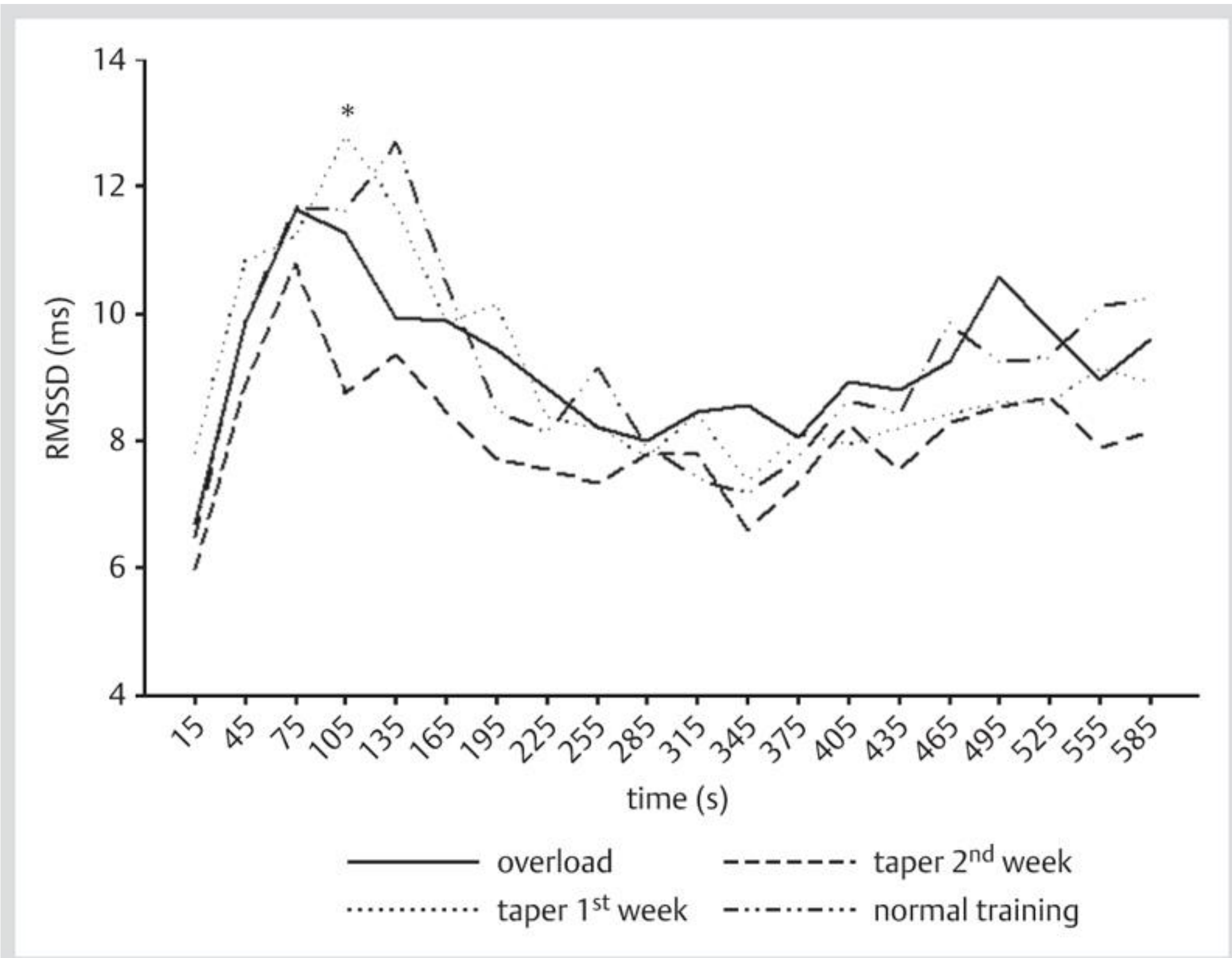
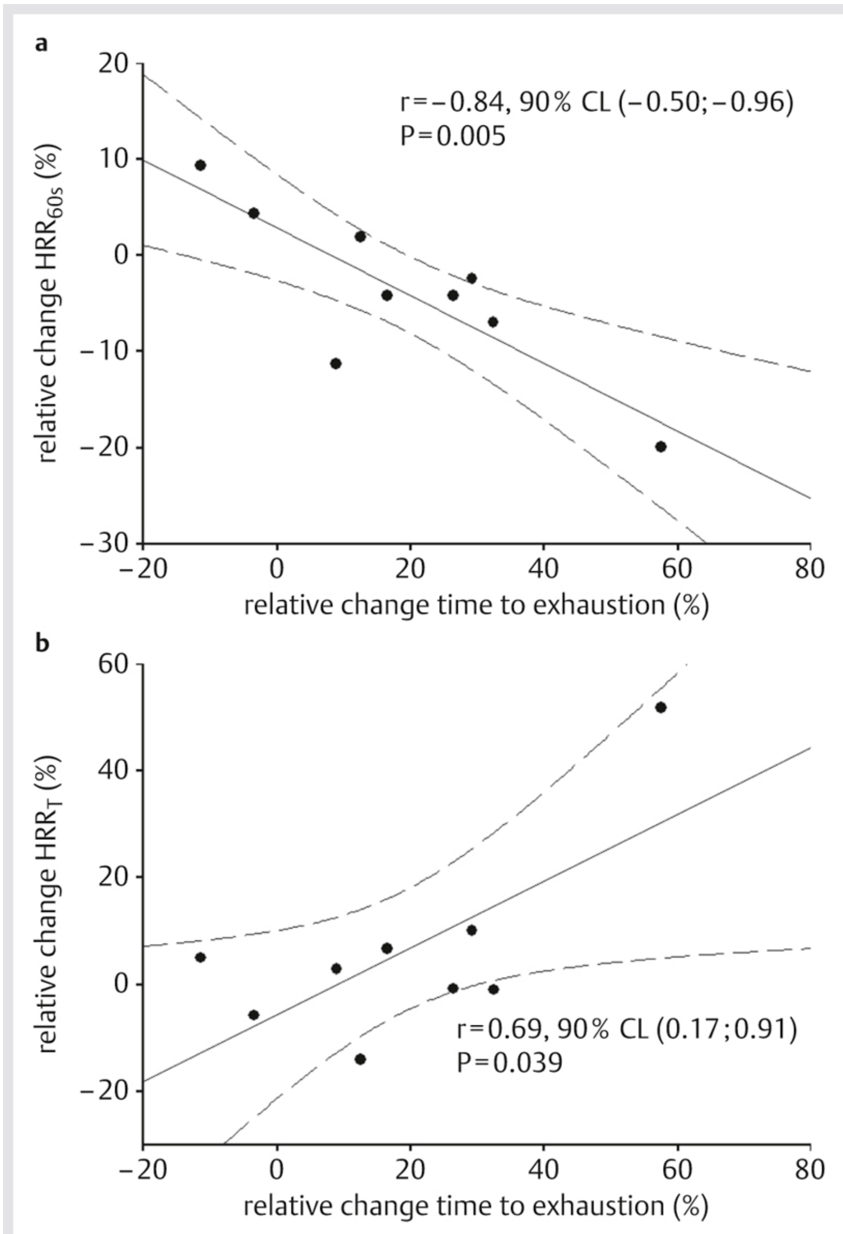


*Fig. 2 Root mean square of successive differences of RR-intervals measured on successive 30-s segments ($RMSSD_{30s}$) during the 10 min recovery period after running to exhaustion at 95% of the velocity associated to $\dot{V}O_{2peak}$. Values of repeated trials (normal training, overload, taper 1st week, taper 2nd week) are plotted without SD for clarity. * P=0.05 for group vs. time interaction between overload and taper 2nd week (90–120 s)*

Figure 2 from Hug et al. (2014)

Finally, a significant correlation was observed between time to exhaustion and heart rate recovery in the first 60 seconds.



| *Fig. 3 a Relationship between the relative change in running time to exhaustion (T_{lim}; s) and relative change in heart rate recovery during the first 60 s (HRR_{60s}; bpm) during the first 2 weeks of tapering. b Relationship between the relative change in running time to exhaustion (T_{lim}; s) and relative change in the time constant of the heart rate decay (HRR_T; s) during the first 2 weeks of tapering.*

Figure 3 from Hug et al. (2014)

Likewise, previous research has shown functional overreaching to be associated with increased parasympathetic activity (29). Correlations between performance and vagal indices have been mixed in other studies (27). As discussed by Hug et al. (2014), Hedelin, Wiklund, Bjerle, and Henriksson-Larsen (2000) found increased parasympathetic activity in an overtrained cross country skier (16). However, in a separate study Helelin, Kentta, Wiklund, Bjerle, and Henriksson-Larsen (2000) found no significant changes in parasympathetic activity in a cohort of canoeists who increased training load by 50 % (15). Meanwhile, in overtrained female endurance athletes undergoing heavy endurance training for 6 to 9 weeks Uusitalo, Uusitalo, and Rusko (2000) found decreased parasympathetic activity (73). In the case of the skier, the subject was 16 years of age, while the canoeists were ages 18 to 23 years. The course of overtraining in the cross country skier had been building for several months. In addition to gender differences than the cross country skier, the female endurance cohort was all over the age of maturity. Only 3 of the 9 athletes in the experimental group actually developed symptoms of overtraining. Hug et al. acknowledge that the differences in findings were likely related to methodology.

Ultimately, practical limitations of cardiovascular tests could limit their utilization by coaches. However, technology such as heart rate monitors available to the consumer could potentially make estimates of heart rate variability, resting heart rate, and other variables viable to athletes and coaches if a consensus is reached for applicability to monitoring training recovery. Development of metrics useful to the consumer as well as the insight into the athletes and exercise physiology may in time lead to parasympathetic metrics useful to coaches.

Inter-Individual Differences in Triathlon Tapering

While USA Triathlon has promoted early specialization in the sport of triathlon, individual athlete backgrounds and training ages of the incoming competitors are varied. One can speculate possible differing tapering needs across the subdisciplines due to differing levels of muscle activity and damage. However, no scientific studies identified thus far have adjusted for differing athletic histories among the triathletes.

The practices of actual athletes can be a valuable source of real world examples of effectiveness. For an example of 1 successful individual, Mujika (2014) evaluated the annual training cycle of a female Olympic triathlete's training plan (39). This athlete had 20 weeks at a dedicated camp setting. This individual's tapering period spanned 3 weeks and three phases. The first week had training reductions of 38, 40, and 24 % for swimming, cycling, and running, respectively. Week 2 of the taper had increases 11 and 25 % for swimming and cycling and a further decrease of 16 % for running. The third week had reductions of 58, 63, and 56 % for swimming, cycling and running, respectively. The final result was seventh place at the Olympic race in London. The aforementioned case of course is only an example for 1 individual and not a template for all to follow. However, for the athlete and the coach it provides some frame of reference as to how an elite might be training before and during the taper for the most important race.

Mathematical modeling has addressed some of the complexities of inter-individual differences among athletes, pertaining to prior training, by using parameters and data pulled from previous research (63,64). In one such model, Thomas et al. (2009) identified a reduction of 32 +/- 6 % for non-athletes and 49 +/- 18 % for athletes in comparing linear tapering strategies with 2-phase tapering strategies. The respective optimal durations as 35 +/- 6 days and 33 +/- 16 days (64). Interestingly the optimal tapers in this research were characterized as 2–phased, which included an increase in volume mid-way through. As the athlete population used for this model consisted of swimmers and the non-athlete population consisted of cyclists the generalizations therein might need to be interpreted cautiously. In contrast, the implications of chronologic age have not been clearly defined by the research for coaching masters athletes across the lifespan. While mathematical modeling might help clarify needs for changing muscle physiology across the lifespan the impetus to drive this area of research may be yet to arrive. Central to the question of optimal tapering strategies across the lifespan is the recovery component of the training cycle. Bishop Jones, and Woods (2008) identified barriers to high quality research in this area, hence limitations of extrapolating to differences across the lifespan (5). These limitations include the lack of consensus on the mechanisms involved in fatigue and the predictability of restoration of muscles from wear and tear, according to the authors.

Athlete history can be an indispensable source of information on tapering design. For example, my own training experience had trial and error leading to my most successful model. I tapered fast exponentially for a period spanning four weeks with a long leveling off of training duration leading up to my half Ironman personal record. I have identified a maximum ride distance of 25 miles the weekend before the "A" priority races, regardless of distance. Training longer than 25 miles adversely affects my performance. I have long believed there was nothing to gain from riding long the weekend before a long course race or a national championship, and experience confirms. My running and swimming distances had less specific formulas, but the long runs were cut down to no more than 10 kilometer the weekend prior and swimming had a shorter taper of one week of 50 % reduction in duration. Low-intensity continuous was a regular feature of workouts, including the Sunday "recovery" session following interval and strength training on Saturday. Most weeks had structured training on all days. Days completely off from structured training facilitated travel and other various obligations.

Gender differences among the cited studies thus far have not identified any differences in appropriate strategies for tapering, but rather in psychological effects therein. In the future, perhaps mathematical modeling will elucidate the dynamics of training age and training load as they relate to optimal tapering strategies if sufficient raw data becomes available. Until then, athlete history, observed and recorded training responses, trial and error, and existing scientific principles will remain the tools for constructing tapering programs.

Publicly Expressed Opinions from USA Triathlon Certified Coaches and Media Resources

University of Arizona triathlon coach Cliff English advises a volume reduction of 50 to 75 % over seven to 10 days for Olympic to half Ironman distances and up to 21 days for Ironman distance (11). English acknowledges the interindividual differences in responses to differing tapering strategies and states that men generally need a longer taper than females. Another concept addressed by coaches is the duration of tapering needed for each of the sub-disciplines. Level 3 USA Triathlon Coach Mike Ricci identifies differing durations of tapering for each sub discipline corresponding to the distance of the race. Ricci identifies running as needing the longer taper and swimming the shortest (61). For Ironman, this consists of 3 weeks for running, two 2 for cycling, 1 week for swimming, and 2.5 weeks out to stop weight training. For half Ironman, he identifies 2 weeks for running, 1 week for cycling, and 1 half week for swimming. For Olympic distance, he recommends 10 days for running, 1 week for cycling, no swim taper, and stopping weight training 1.5 weeks out. For sprint distance he recommends 4 days for all disciplines and stopping weight training 1 week out. This general advice is difficult to evaluate for confluence with training protocol studies as it does not clearly adjust for the importance of the race and the training distances. So, for the athlete who participates in an Olympic distance while training for Ironman the durations of taper components would be unclear. The wide-ranging different viewpoints on proper tapering necessitate expounding the important objectives of tapering and clarify what recovery practices hasten or hinder the process.

In 1985 Glenn P. Town characterized the taper as follows: “The purpose of the taper is to allow for maximum physical healing, mental and emotional preparation, and optimal storage of fuels.” Town identifies active recovery as the best means of recovery. He cites research by Tipton noting that healing occurs more quickly when exercising as opposed to “resting.” In so doing musculoskeletal stiffness would be averted and blood delivery to muscles would be optimized. However, completely restocking the fuels may require one full day without training, according to Town (66). From the standpoint of reducing mental stress, time would be freed to address other life concerns. Likewise, the coach and the athlete can anticipate taking travel and various needs necessitating an occasional day off from structured training, which will serve to reduce stress heading into a major race. In turn, training plans could be set to address the miscellaneous needs of the athlete so that stress during race week can be minimized and the benefits of the taper can be fully realized. In the Triathlon Training Bible: Second Edition, Joe Friel advised tapering 10 to 21 days, depending on the fitness level of the athlete (12). Friel advised maintaining frequency and intensity. The description of the above taper pointed to a progressive pattern. In the case of a 21-day taper period this would necessitate cutting 20 % for each week, 30 % each week for a 2-week taper, and 50 % for the whole period for a 1-week taper according to Friel. Friel gave additional general advice to train easy for any other workouts in the period. Absent from this model is an exponential decay pattern. In the book Triathlon Science Joe Friel referenced Neufer et al. (1987) who investigated the effects of reduced training frequency on swimming performance, where training was reduced from 6 days per week to 3 days per week or 1 day per week (13). It was found that 3 days per week maintained stroke rate and distance per stroke. Friel mentioned that the data available to date of publication was limited for events lasting several hours. Importantly, Joe Friel advised using recommendations only as guidelines. In turn, he advises, the coach and the athlete must work together to reach a workable formula, especially with the higher performing athletes. In Lore of Running: Fourth Editition, Tim Noakes reached similar conclusions about high-intensity tapering being an optimal approach (43). He speculated that the main effect of high-intensity tapering is in the brain. In the context of running competition Noakes advised tapering consist of training "as little as the mind will allow," albeit at a higher intensity. One example of a book directed at novice triathletes addresses taper duration. In Ironman First Triathlon: Your Perfect Plan for Success, author Lucy Smith identifies the taper as lasting 5 to 7 days (57). The purpose was identified as activating range of motion for race day. Also, the extra time affords opportunity to address other life concerns. Training bouts in this phase consist of short periods of race pace activity. The aforementioned simple descriptions apparently correspond to a sprint distance training load. In contrast, the more comprehensive distances focused on in Race Week by Paul Rejensburg identify the taper as being as long as 4 weeks with the primary purpose being to restock glycogen stores (49). Training is to be cut by 50 % while maintaining intensity. The taper period plan examples showed the periods consisting of interval workouts. Starting Out Training for Your First Triathlon Competition by Paul Huddle depicted a taper period of 2 weeks with a decreased training volume with intensity maintained (25). All of the workouts were time-based rather than distance-based. The books reviewed herein were not at odds with the science of tapering, but as they were aimed apparently at relative newcomers they don't assimilate an athlete history. Principles of tapering were not clearly defined but rather exact details of example plans were given.

Advice from lay resources and coaches remains varied and ranges from general to specific but underscore the importance of reduced duration while maintaining or increasing intensity across the taper period.

Implications for Coaches and Athletes

The research in this review have found that a properly executed taper enhances race performance when it follows an overload period without symptoms of overreaching. The sport of triathlon poses particular challenges for optimizing tapering strategies as there are potential training interactions across sub disciplines and there are many ways of manipulating training. Individual studies are limited in what they can evaluate in the lab and extrapolate to longer distances on the race courses. Additionally, the use of less specific training such as the different competitive strokes during the taper period have not been scientifically evaluated for impact on triathlon performance. The difficulty of scientifically evaluating every possible variation in training and the interests and desires of individual athletes underscore the nature of coaching as being an art and a science. Further, the format of tapering will depend partly on the importance of the race during the season. The amateur athlete may consider how much performance they are willing to sacrifice in lower priority races in order to attain the ultimate goal of the championship race. For the professional triathlete racing biweekly, the taper duration can be expected to be minimal. In turn, more of their time during the season can be devoted to optimizing nutrition, sleep, and other factors in athletic performance.

To date research on tapering has consistently identified shorter duration and maintained or slightly increased intensity as strategies conducive to performance. Meanwhile, the evidence for training frequency suggests that maintaining frequency at least 80 % of pre-taper training levels is conducive to optimal performance. While some days of complete rest during the taper has been advocated by some coaches, these non-training days have not been precisely defined in the research highlighted in this review. Thus, the needs of the individual athletes in coordination with coaches and athletic trainers may supersede and published research or official positions. Any prescription of complete rest will need to be clarified for details of time spent and considered in light of evidence on metabolism and health as well as athlete history. Training prescription will also need to be coordinated with individual presenting needs and interests in order to optimize performance with due consideration to extraneous needs. No evidence discussed thus far has shown that short, low-intensity workouts interfere with the training recovery process during the taper period. However, the evidence reviewed does point to the need to reduce training duration and effectively distance. The principles of tapering theory must be kept in mind in order to fulfill the purpose of alleviating fatigue and promoting healing. Athletes in the field can be a valuable resource for determining their individual needs.

All methods of training produce responders and non-responders. Differences in responses across individuals may be linked chronological age, training age, training volume during the overload period, individual muscle fiber composition, differences in circulating hormones and hormone sensitivities, factors affecting blood cell turnover, state of health, and other possible variables. Coaches and athletes alike may need to have specific objectives for change during the tapering period to strategize the format and maximize response. If these objectives are met and established by functional tests, no further training adjusts may be necessary. Effective tests of recovery, if available, might answer questions of progress between days with time trials and races. Other than time trials, no absolute functional, non-invasive tests fitness tests have been identified for the course of the tapering period to predict ultimate race performance. However, subjective tests and psychological profiles may be useful in filling the gaps. Anatomic and physiologic changes identified with tapering for single discipline sports can be expected to be applicable to triathlon. Overtraining evidently needs to be corrected prior to the taper period, as the performance improvements from tapering are outweighed by other training and athlete history variables. Thus far, the paucity of triathlon coaching in the institutional setting may limit incentives to maximize athlete performance. Individual professional coaches serve athletes with varied objects ranging from finishing to maximizing personal performance. The narrow focus of triathlon coaching may limit the availability of clients in a geographic area thereby leading to increased online coaching. As online platforms provide sponsorship at coaching summits, remote coaching may be increasingly promoted indirectly by USA Triathlon, leading to potentially conflicting information from different sources. In turn, coaches with limited or no athlete contact may be leading future coaching certification clinics. With triathlon as an emerging NCAA sport, all dimensions of training strategies including tapering may become better established as coaching is linked more directly to team performance. While scientific investigation may provide a framework for structuring a taper, optimal strategies will need to be created with the athlete’s involvement and due consideration to history of training and race performance.

Final Recommendations

For Coaches

One of the key roles of the coach is monitoring the response of the training stimulus. The coach should help construct an overload period that will continue to challenge the athlete. However, if signs of overreaching are present, they should be addressed and corrected early on. The tapering phases of the triathlon macrocycles should unload fatigue while continuing to provide training stimuli in order to optimize race performance. For the seasoned athlete who has had a complete, uninterrupted off season with major training and fitness objectives met, performance gains from tapering may exceed those otherwise gained across the competitive season with consistent training. In light of the body of evidence, the seasoned athlete would best err towards a longer tapering period to maximize performance gains, especially if signs of functional overreaching are present. Physiologic changes result from substantial volume reductions, which were varied throughout the research. Aim for at least 40 % and adjust up to 60 percent or greater if the athlete is the athlete is comfortable with the plan. The tapering program should be progressive, ideally exponential, should maintain frequency to at least 80 %, should slightly increase intensity if tolerable (while still preparing the same energy systems), and be specific to the forthcoming race. In contrast to the above scenario, the athlete the athlete should choose shorter progressive tapering strategies if they have not plateaued in their training, races bi-weekly or more frequently, or implements a carbohydrate loading strategy. Another consideration for the taper period is the length of the race, length of the training distances, and concomitant fatigue from the overload period. These factors provide additional reasons to err towards a taper period of 2 weeks or more. However, individual athlete needs must be considered with attention to any symptoms, travel conditions, interests, and other life circumstances. The athlete and the coach should work out the program details with these parameters in mind. Individualized advice for the non-training days should help keep the body and mind functional for race performance. This process should be tested on races of medium to low priority before implementation on the most important races. The tapering program should be monitored like the rest of the training cycle to prevent and alleviate functional overreaching. Tests of mental state for monitoring training will likely be the most practical and cost-efficient method of monitoring; specific recommendations therein can be sought elsewhere. Whatever tapering strategy is implemented, it should be conducive to the needs of the athlete in order to fulfill the rewards of triathlon participation. While the example opinions cited in this review are not necessarily well-founded by science, there is value to learning from personal experience. Remember to know the motives of the athlete and continue to shape your understanding as new information emerges. Work with the athlete to develop a suitable plan.

For Athletes

If the triathlete had an overload period and perceives a high training volume for a period of several months, then the athlete should fully taper for the important race to optimize performance while less important races may receive little or no tapering, depending on the judgement of the athlete and the coach. However, if training volume has been too low to accumulate fatigue then tapering is not necessary as there is nothing to unload. If the athlete is experiencing chronic fatigue, mood disturbances, and other symptoms of overreaching then the athlete must reduce their training load and take occasional days off from training until symptoms subside. Overreaching should be remedied as soon as symptoms emerge in order to benefit from tapering before the big race. Tapering should reduce training volume by at least 40 percent, but target a range of 40 to 60 percent to start with. Triathletes must aim to maintain training frequency and intensity during the taper period. For courses longer than Olympic distance, a 2-week taper period is a good starting point to maintain fitness and unload fatigue. For a training cycle consisting of preparing for Olympic distance or shorter races only, the athlete may experiment in the range of 1 to 2 weeks to optimize race performance. Maintain or slightly increase the pace by 10 % to continue preparation of the same energy systems to race. If you are able to sustain a slightly higher intensity during the training then the athlete is meeting the basic performance objectives during the taper period. Up to 1 additional day off per week can be implemented during this period provided that that other considerations such as travel do not additionally displace training. Prioritize routines conducive to good health such as sleep and nutrition as advised elsewhere. Try having a little extra fun with the extra time off from training during the taper period. Finally, the athlete should trust their instincts and err towards lower training volumes during the taper period. Remember that experience is a valuable source of training insight.

For Future Research

In order best apply research findings, there should be consistent terminology in the studies and recommendations. I propose using "pace" to refer to a particular training speed and intensity to refer to energy systems in use and/or rate of perceived exertion. I recommend describing non-training days in both the design and the results of future research in order to help explain any differences in findings across research as well as to ultimately translate into clear recommendations. Another important question for research is how tapering strategies should vary across race distances. Additionally, the role of gender as it relates to tapering should be investigated to help plan training cycles, especially for teams as individualization may be more cumbersome. Future research questions may address individual needs and how these applied differences can lead to better customized training plans.

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