Effects of Tapering on Performance: A Meta-Analysis

LAURENT BOSQUET[1,2], JONATHAN MONTPETIT[1], DENIS ARVISAIS[1], and IÑIGO MUJIKA[3,4]

[1]*Department of Kinesiology, University of Montreal, Montreal, CANADA;* [2]*Faculty of Sport Sciences, University of Lille, Ronchin, FRANCE;* [3]*Department of Research and Development, Athletic Club Bilbao, Lezama, SPAIN; and* [4]*Department of Physiology, Faculty of Medicine and Odontology, University of the Basque Country, Álava, SPAIN*

ABSTRACT

BOSQUET, L., J. MONTPETIT, D. ARVISAIS, and I. MUJIKA. Effects of Tapering on Performance: A Meta-Analysis. *Med. Sci. Sports Exerc.*, Vol. 39, No. 8, pp. 1358–1365, 2007. **Purpose:** The purpose of this investigation was to assess the effects of alterations in taper components on performance in competitive athletes, through a meta-analysis. **Methods:** Six databases were searched using relevant terms and strategies. Criteria for study inclusion were that participants must be competitive athletes, a tapering intervention must be employed providing details about the procedures used to decrease the training load, use of actual competition or field-based criterion performance, and inclusion of all necessary data to calculate effect sizes. Datasets reported in more than one published study were only included once in the present analyses. Twenty-seven of 182 potential studies met these criteria and were included in the analysis. The dependent variable was performance, and the independent variables were the decrease in training intensity, volume, and frequency, as well as the pattern of the taper and its duration. Pre–post taper standardized mean differences in performance were calculated and weighted according to the within-group heterogeneity to develop an overall effect. **Results:** The optimal strategy to optimize performance is a tapering intervention of 2-wk duration (overall effect = 0.59 ± 0.33, $P < 0.001$), where the training volume is exponentially decreased by 41–60% (overall effect = 0.72 ± 0.36, $P < 0.001$), without any modification of either training intensity (overall effect = 0.33 ± 0.14, $P < 0.001$) or frequency (overall effect = 0.35 ± 0.17, $P < 0.001$). **Conclusion:** A 2-wk taper during which training volume is exponentially reduced by 41–60% seems to be the most efficient strategy to maximize performance gains. This meta-analysis provides a framework that can be useful for athletes, coaches, and sport scientists to optimize their tapering strategy. **Key Words:** TRAINING INTENSITY, TRAINING VOLUME, TRAINING FREQUENCY, PERIODIZATION

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The taper is a reduction in the training load of athletes in the final days before important competition, with the aim of optimizing performance. This reduction of the training load can be achieved through the alteration of several components, including the training volume, intensity, and frequency (72), as well as the pattern of the taper (i.e., progressive or step taper) and its duration (25,28,39,46). The taper is widely used by athletes participating in a wide range of sports differing in their biomechanical and physiological demands to gain a performance edge over competitors. In fact, significant improvements have been reported after tapering for runners (29), swimmers (48), cyclists (51), rowers (32), and triathletes (34).

The difficulty for athletes, coaches, and sports scientists consists in finding the strategy that will maximize the decrease in accumulated fatigue while retaining or further enhancing physical fitness, thus leading to peak performance. Many strategies to decrease the training load have been reported in the tapering literature, most of them leading to an improvement in performance and/or its physiological correlates (25,28,39,49,55). Some studies have suggested that the reduction in training volume should be substantial, somewhere near 85% of normal training volume (28), whereas others have reported similar improvements in performance after a 31% reduction (3). This decrease in training volume is generally obtained through the decrease in the duration of each training session (3,42,52). However, some studies prefer to manipulate the training frequency (i.e., the number of training sessions per week) to decrease weekly training volume (8,31,35). The duration of taper is also open to wide variations in the literature. Although most studies have used a 2-wk taper (3,30,31,34), significant improvements in performance also have been reported for very short (<7 d) (52) or very long tapers (>28 d) (40).

Address for correspondence: Laurent Bosquet, Ph.D., Department of Kinesiology, University of Montreal, CP 6128, succ. centre ville, Montreal (Qc) Canada H3C 3J7; E-mail: laurent.bosquet@montreal.ca.
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TABLE 1. Effects of moderator variables on overall effect size for taper-induced changes in performance.

Categories	Overall Effect Size: Mean (95% CI)	N	P
Decrease in training volume			
≤ 20%	−0.02 (−0.32, 0.27)	152	0.88
21–40%	0.27 (0.04, 0.49)	90	0.02
41–60%	0.72 (0.36, 1.09)	118	0.0001
≥ 60%	0.27 (−0.03, 0.57)	118	0.07
Decrease in training intensity			
Yes	−0.02 (−0.37, 0.33)	63	0.91
No	0.33 (0.19, 0.47)	415	0.0001
Decrease in training frequency			
Yes	0.24 (−0.03, 0.52)	176	0.08
No	0.35 (0.18, 0.51)	302	0.0001
Duration of the taper			
≤ 7 d	0.17 (−0.05, 0.38)	164	0.14
8–14 d	0.59 (0.26, 0.92)	176	0.0005
15–21 d	0.28 (−0.02, 0.59)	84	0.07
≥ 22 d	0.31 (−0.14, 0.75)	54	0.18
Pattern of the taper			
Step taper	0.42 (−0.11, 0.95)	98	0.12
Progressive taper	0.30 (0.16, 0.45)	380	0.0001

In addition to the total decrease in training load, the way to decrease it can influence the results, whether it is a single stepwise reduction or a progressive exponential reduction with a fast or eventually a slow decay (3). Alternative strategies are also being tried by athletes in different sports. One of these alternative strategies consists in an advanced reduction in the training load, followed by a subsequent increase in the lead-up to competition (unpublished observations). The rationale behind this tapering design is that the athlete would take advantage of reduced fatigue levels to enhance training tolerance and respond effectively to the training undertaken during the taper, as suggested by recently developed variable dose–response mathematical models (6,67). Unfortunately, no experimental data are available regarding the suitability of this tapering mode in highly trained athletes.

As indicated by the information above, a wide range of tapering strategies are currently being used by athletes and their support teams in view to optimize sports performance. The question then arises to determine whether there is an optimal strategy suitable for most competitive athletes, as suggested by Mujika and Padilla (46), or if different patterns of training load reduction can lead to similar improvements in performance. The purpose of this investigation was to assess the effects of the alterations of taper components on performance in competitive athletes, through a systematic review (or a meta-analysis) of the literature.

METHODS

Literature search. The databases Embase, Kinpubs, Physical Education Index, PubMed, SportDiscus, and Web of Science were searched using the terms (taper* AND (performance* OR competition* OR training) AND (sport* OR exercise* OR swim* OR cycli* OR runn* OR rowi*). The reference lists of the articles obtained were searched manually to obtain further studies not identified electronically. This led to the identification of 182 potential studies for inclusion in the analysis.

Criteria. Criteria for study inclusion were that participants must be competitive athletes (168 articles fulfilled this criterion), the study must employ a tapering intervention and give all details about the procedures used to decrease the training load (128 articles), the study must use actual competition or field-based criterion performance data to assess performance capacity (43 articles), and the study must include all necessary data to calculate effect sizes (i.e., number of subjects, mean and standard deviation) (32 articles). Criterion for study exclusion was that the set of data has been previously published in another article that has already been included in the present analyses (5 articles). A total of 27 studies were included in the analysis (2–4,8,14, 16–20,22,26,29–32,34,35,40,42,43,48,51,52,54,63,70).

Coding for the studies. Each study was read and coded independently by two investigators using the following

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

Categories	Swimming		Running		Cycling	
	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

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

moderator variables: the performance capacity, the modalities of the tapering intervention, including the decrease in training volume, intensity, and frequency, the pattern of the taper and its duration. An interval scale was used for the coding of the decrease in training volume and the duration of the taper, and a nominal scale was used for the remaining variables. The coding agreement between investigators was determined by dividing the variables coded the same by the total number of variables. A mean agreement of 0.90 is accepted as an appropriate level of reliability in the coding procedure (58). Mean agreement was 0.927 in our study. Each coding difference was scrutinized by both investigators together and was resolved before the analysis.

Statistical analysis. Pre–post taper standardized mean differences in performance were calculated, and weighted according to the within-group heterogeneity to develop an overall effect. Statistical significance was set at $P < 0.05$ level for all analysis. The scale proposed by Cohen (9) was used for interpretation. The magnitude of the difference was considered either small (0.2), moderate (0.5), or large (0.8). All calculations were made with Review Manager 4.2.8 (The Nordic Cochrane Center, The Cochrane Collaboration, Copenhagen, Denmark).

RESULTS

Overall effect sizes for tapering induced changes in performance are shown in Table 1 for each moderator variable. Specific swimming (eight studies, N = 249), cycling (six studies, N = 80), and running (nine studies, N = 110) data are presented in Table 2. The dose–response curves for the overall effect of duration and percentage decrement in training volume on performance are shown in Figures 1 and 2, respectively. According to the reported data, in these competitive athletes, maximal gains are obtained with a tapering intervention of 2-wk duration, where the training volume is exponentially decreased by 41–60%, without any modification of either training intensity or frequency. This generic taper can differ slightly depending on the locomotion mode. The expected performance gains are small to moderate for each of these categories (0.35 < effect size < 0.72, Table 1).

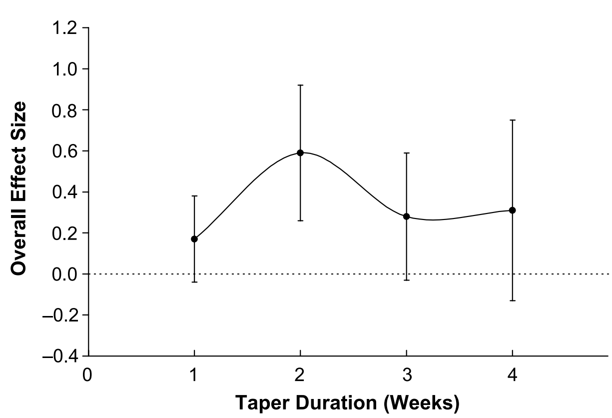

FIGURE 1—Dose–response curve for the effect of taper duration on performance.

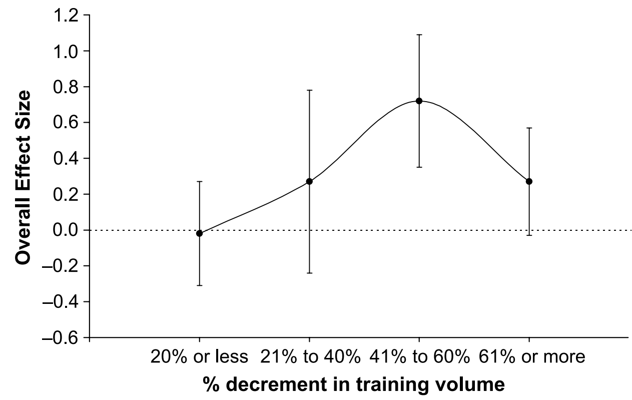

FIGURE 2—Dose–response curve for the effect of percent decrement in training volume during taper on performance.

DISCUSSION

The purpose of this investigation was to assess the effects of the alterations of taper components on performance in competitive athletes, through a meta-analysis of the literature. In accordance with previous suggestions (46), we found that maximal gains are obtained with a tapering intervention of 2-wk duration, where the training volume is exponentially decreased by 41–60%, without any modification of either training intensity or frequency.

Reduction in training load. Training load can be decreased through the alteration of training volume, intensity, and frequency (72). In agreement with previous suggestions (28,46), this meta-analysis has confirmed that performance improvement was more sensitive to the reduction in training volume (Table 1). We computed the decrease in training volume as the area under the training volume–time curve. However, some papers did not provide adequate data to make a precise estimation of this area. It is, therefore, acknowledged that measurement error is present at different degrees depending on the studies. We expect that the use of four categories with relatively wide ranges will minimize the effect of imprecision on the dose–response relationship.

Maximal performance gains are obtained with a total reduction in training volume of 41–60% of pretaper value. Training volume can be altered through the decrease of the duration of each training session and/or the decrease of training frequency. It seems that the first strategy should be preferred, because decreasing training frequency does not result in a significant improvement of performance (Table 1). It should be kept in mind that there is a large variability between studies, as evidenced by the wide 95% confidence interval (Table 1). The decrease in training frequency often interacts with other moderator variables

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like training intensity or the form and duration of the taper, which makes it difficult to isolate precisely its effect on performance. A more conservative approach would be to recommend maintaining training frequency at 80% or more of the pretaper value (43,46).

As already pointed out by other researchers (28,33,39, 46,55), it seems clear that the training load should not be reduced at the expense of training intensity (Table 1), probably because it is a key parameter in the maintenance of training-induced adaptation during the taper (49). It is worth noting, however, that the four eligible studies that decreased training intensity during the taper period were included in the computation of the overall effect of other moderator variables. It is legitimate to think that it may have led to an underestimation of the true overall effect of these moderator variables. Therefore, we repeated the analyses by discarding the experimental groups of these four articles, and we found no difference either on the effect sizes or on the global dose–response relationship.

Duration of the taper. We found a dose–response relationship between the duration of the taper and the performance improvement. Duration of 8–14 d seems to represent the borderline between the positive influence of fatigue disappearance and the negative influence of detraining on performance. Performance improvements can also be expected after 1-, 3-, or 4-wk tapers (Table 1, Fig. 1). However, as suggested by 95% confidence intervals, negative results may be experienced by some athletes. This interindividual variability in the optimal taper duration has already been highlighted by some mathematical modeling studies (40,41,67). Differences in the physiological and/or psychological adaptation response to reduced training (40,41,48), as well as the use of an overload intervention in the weeks before taper (67), are some of the variables that can account for this variability.

Pattern of the taper. Mujika and Padilla (46) identify four types of taper patterns: linear taper, exponential taper with slow or fast time constant of decay of the training load, and step taper. Because the pattern is not always precisely detailed in the included studies, we gathered linear and exponential tapers together into one single pattern named *progressive taper*. As can be seen in Table 1, the majority of studies used a progressive decrease in training load. Our results agree thoroughly with the results of Banister et al. (3), who report higher performance improvements after a progressive taper when compared with a step taper. We were not able in this study to address the effect of the kind of progressive taper (i.e., linear or exponential with fast or slow decay of the training load) on performance. Again, actual recommendations rely on the work of Banister et al. (3), who suggest that a fast decay was more beneficial to performance than a slow decay of the training load.

Expected performance improvements. Tapering is a training strategy to enhance performance in the most important athletic competitions. Because performance is a complex system whose whole is more than the sum of its parts, specific event performance is the most suitable outcome to evaluate the effectiveness of a tapering intervention. This is the reason why all studies using other measures than actual competition or field-based criterion performance data to assess performance capacity were not included in the analyses. When using the scale of Cohen (9) for the interpretation of the effect size, expected performance improvements are most often small, and occasionally moderate. When expressed as a percent difference, performance modifications range from −2.28% (54) to 8.91% (19), with a mean improvement of 1.96%. This difference could be considered as meaningless if the population of interest were not competitive athletes. As highlighted by Hopkins et al. (23), the smallest enhancement of performance that has a substantial effect on a top athlete's chance of a medal is about one third of the typical variation of performance in competition. This has been shown to be approximately 0.5–1% in both swimming and running (24,64). In this context, the gains that can be expected after a taper intervention, as little as they are, may have a major impact on an athlete's success in major competitions. An illustration of this is provided by Mujika et al. (48), who report that the magnitude of taper-induced improvements in performance in the swimming events (2.2%) were of similar order to the differences between the gold medalist and the fourth place (1.62%) or between third and eighth place (2.02%) at the 2000 Sydney Olympics.

Possible mechanisms. A number of physiological changes may account for the tapering-induced improvements in performance capacity. Maximal oxygen consumption ($\dot{V}O_{2max}$) has long been used as a determinant of performance (60). The taper-induced hypervolemia and enhanced red cell production (42,47,62), together with an increase in oxidative enzyme activity (52,53,62), may contribute significantly to the increase in oxygen extraction reported by Neary et al. (54) and, more generally, to the increase in $\dot{V}O_{2max}$ observed in several studies (16,30,34,51,52).

The energy cost of exercise is another important determinant of performance (15). As reviewed by Mujika et al. (49), results are disparate, with the discrepancies probably related to factors such as differences in the training and tapering programs and the caliber of the athletes. Nevertheless, significant improvements have been reported both in swimming (14,31) and running (26,29), but not in cycling. It has been speculated that biomechanical and neural factors could explain the taper-induced improvement in the energy cost of exercise (14,29). The neural hypothesis is consistent with the increase in strength and power—two factors known to significantly influence the energy cost of exercise (21), as has been reported consistently in the taper literature (22,31,62,68).

The capacity to sustain a high percentage of $\dot{V}O_{2max}$, also named *aerobic endurance* (5), is the last determinant of performance identified by DiPrampero et al. (15). As outlined by Péronnet and Thibault (56), the physiological basis of aerobic endurance is not clearly understood.

Outstanding aerobic endurance can be associated with a combination of factors, including a high percentage of type I muscle fibers, the capacity to store large amounts of muscle and/or liver glycogen, the capacity to spare carbohydrate by using more fatty acids as energy substrate, and the capacity to efficiently dissipate heat. If the taper has been shown to affect significantly the contractile and metabolic properties of single muscle fibers (52,68), there are actually no data available to support the hypothesis of a modification in fiber distribution. It also does not seem that substrate use is affected, because the respiratory exchange ratio (RER) is most often unchanged after a taper intervention (29,51,59). However, the 13–34% taper-induced increase in muscle glycogen content observed both in men and women (52,53,62,71) could, undoubtedly, contribute to improve aerobic endurance.

If these physiological changes can occur very rapidly when training load is decreased, they also are prone to a rapid loss when the training stimulus is insufficient (44). In fact, Coyle et al. (11), as well as Houmard et al. (27), found that a few days were enough to decrease significantly the blood volume, which negatively affected the cardiovascular function by decreasing both the stroke volume (11) and the cardiac output (13). Enzymatic activity, including oxidative enzymes and glycogen synthase, decreases also very rapidly when the training stimulus is insufficient (12,27,37); this may contribute to the rapid decrease in $\dot{V}O_{2max}$ and glycogen stores reported in the detraining literature (10,11,13,27). Altogether, these results show that taper-induced positive physiological changes are only transitory and may return very rapidly to pretaper values or, eventually, to initial values in the case of a long-term insufficient training stimulus (45). Whence the difficulty to find the taper strategy that will allow the athlete to recover and overcompensate adequately from prior heavy training loads while avoiding detraining.

Practical considerations. According to our results, a tapering intervention of 2-wk duration, where the training volume is exponentially decreased by 41–60%, without any modification of either training intensity or frequency, is the strategy that will maximize the probability to obtain significant improvements in performance. From a practical point of view, it is important to determine whether this "optimal" taper is a generic one, or whether it differs according to the sport, the gender, or the fatigue status before the taper.

Specific swimming, cycling, and running data are shown in Table 2. Rowing was not considered because the total number of subjects (two studies, $N = 23$) was insufficient to address all the moderator variables used in this meta-analysis. Although the number of swimming, cycling or running subjects per moderator variable was also insufficient to provide each sport with specific recommendations, it was possible to identify some trends. The first, indisputable one is the need to maintain training intensity, whatever the mode of locomotion. If a 41–60% decrease in training volume seems to be optimal in swimming, we were not able to find a similar cutoff value in cycling and running, the optimal decrease being somewhere between 21 and 60%. A period of 8–14 d seems to represent the optimal taper duration in cycling and running. It should be noted, however, that significant improvements can be expected from longer taper durations in swimming, but also that the number of cycling and running subjects for such durations is insufficient to test this hypothesis with adequate statistical power ($N = 10$ in running and 0 in cycling for 15–21 d and 22 d or more). Finally, there seems to be some controversy in cycling about the pattern of taper that should be preferred, but also to determine whether a decrease in training frequency should be used to decrease training volume.

Because sex has been shown to affect some of the mechanisms possibly leading to an improvement in performance, such as the capacity to increase glycogen stores (66), it is quite legitimate to question the applicability of this strategy to women. Among the 27 included studies, only nine of them used a mixed sample, and only three of them provided separated results that would allow comparisons between males and females. Smith (63) did not report any sex difference in the amplitude of performance improvement after a 1-wk taper in 6 female and 10 male elite rowers. These results were in accordance with Mujika et al. (40), who found no difference between 8 female and 10 male elite swimmers after two tapers of 3- and 4-wk duration. In a more recent study, Mujika et al. (48) registered the performance change of 49 female and 50 male elite swimmers in the final 3-wk taper leading to the Sydney 2000 Olympic Games. They found a higher improvement in males than in females in freestyle events (2.54 ± 1.5 vs $1.60 \pm 1.33\%$, $P < 0.05$), but not in form events (backstroke, breaststroke, butterfly). The observational nature of this study did not allow the authors to provide any psychological and physiological explanation for this difference. Other confounding factors such as shaving or the use of different swimming suits may have affected the results. With the exception of this possible sex effect on the magnitude of taper-induced performance improvement, we found no apparent evidence questioning the generalization of our results to women.

Another important practical consideration is whether the optimal taper depends on the severity of fatigue an athlete carries into the taper process. The theoretical modeling work of Thomas and Busso (67) clearly shows that using an overload procedure before the taper results in higher performance gains, but also that taper duration and percentage decrease in training load should be adapted (i.e., increased) to dissipate this extra accumulated fatigue. Despite this sound theoretical background, very few experimental studies addressed this topic. This situation probably arises from the difficulty to quantify fatigue. The overreaching/overtraining literature of the past two decades clearly indicates that there exists no pathognomonic clinical sign of severe fatigue (69). An affordable and very interesting tool to assess fatigue levels is probably the profile of mood states (POMS) (36). If several taper-studies included the POMS in their measures (4,17,22,34,38,57), only two of them used it as a tool to quantify initial fatigue (4,34). Margaritis et al. (34) used a total mood disturbance (TMD) score with the purpose of identifying overreaching or overtraining. However, they did not provide cutoff values that would help to classify the subjects into one of these categories. In the study by Berger et al. (4), eight elite pursuit cyclists completed the POMS and a simulated 4-km pursuit performance test throughout a 6-wk period, including a 1-wk baseline, a 3-wk overload, and a 2-wk taper. They found the TMD score to increase after the overload period and to decrease below baseline values after the taper period. If it is clear from this study and many others (4,17,22,34,38,57) that TMD or subscales scores are sensitive to fatigue, there is still difficulty in delineating cutoff values that would allow classification of subjects or comparison of studies.

Athletes' diet also may affect the benefits that can be expected from a well-designed taper. Margaritis et al. (34) have reported the daily energy intake, energy expenditure, body mass, and body fat of 20 male long-distance triathletes during 4 wk of overloaded training and then 2 wk of taper. Energy intake did not change between both phases (15.0 ± 3.2 vs 15.0 ± 3.3 $MJ \cdot d^{-1}$), whereas energy expenditure decreased from 17.0 ± 1.9 to 12.1 ± 1.2 $MJ \cdot d^{-1}$ ($P < 0.05$). Total body mass did not change during the taper (67.9 ± 3.6 vs 67.8 ± 3.2 kg, NS), but percent body fat increased from 11.4 ± 3.7 to 11.8 ± 3.7% ($P < 0.05$). Consequently, care should be taken to match energy intake with the reduced energy expenditure that characterizes the taper. Muscle glycogen concentration has been shown to increase during the taper (52,53,71). Because the amplitude of glycogen supercompensation has been associated with the amplitude of performance improvement in a 40-km time trial (52), it is important to use nutritional strategies that will maximize the replenishment of glycogen stores. Walker et al. (71) found in six eumenorrheic women that glycogen supercompensation and performance in a constant-power test at 80% $\dot{V}O_{2max}$ were higher after a 7-d taper with a high-carbohydrate diet (78% carbohydrate) during the final 4 d compared with a moderate-carbohydrate diet (48% carbohydrate) for 7 d. Consequently, a rich carbohydrate diet seems to be an important component of a successful taper.

Limits. Specific event competition or field-based criterion performance data were designed as the dependant variable to test the effectiveness of taper strategies. Correct interpretation of our results relies on the assumption that both pre- and posttaper performances were indeed maximal. Although this methodological consideration was of primary importance, we found very few studies using a criterion to control this parasite variable. Neary et al. (51,52,54) made an effort in this direction by taking the rating of perceived exertion at the end of each performance test. They reported no difference between pre- and posttaper values, suggesting that efforts were at least of similar difficulty. Houmard et al. (29) computed the intraclass coefficient of correlation (ICC) between pre- and posttaper values to assess the consistency between datasets. They reported an ICC of 0.99, suggesting that both absolute and relative errors were low. The fact that other studies included in this meta-analysis did not control this point probably limits the interpretation that can be made from their results. In fact, a possible placebo effect can interact with a natural tendency to go deeper during the last performance test and lead to an overestimation of taper-induced performance gains. It should be noted, however, that 10 of the 27 studies included in this meta-analysis used competition data (2,17,18,20,22,31,40,42,43,48), where motivation to give an all-out effort was probably the same for each test because, in addition to the competitive stake, they were part of a more global competition schedule. Moreover, the 17 remaining studies used field-based performance tests that have been shown to be very reliable (1,50,61,65), thus limiting the error of measurement.

The aim of a meta-analysis is to combine the body of literature on a given topic to propose evidence-based conclusions. In this study we identified numerous moderator variables to describe as close as possible the diversity of tapering strategies currently used by coaches and sport scientists. A prerequisite to make valid comparisons is to have roughly the same number of subjects per moderator variables. With the exception of the decrease in training volume, most of the remaining independent variables did not meet this condition. Although a duration of 8–14 d seems to be optimal in terms of performance gains, it has to be recognized that additional data are needed to test the real effectiveness of longer taper durations (N = 164, 176, 84, and 54 for 1-, 2-, 3-, or 4-wk taper durations, respectively). The choice of a given pattern is also complicated by the difference in the number of subjects (N = 98 and 380 for step and progressive taper, respectively). A lower statistical power make step taper performance gains nonsignificant, whereas the overall effect is higher than that of progressive taper (Table 1). The same is true for the decrease in training frequency. Future studies should test these conditions, to verify whether the predictions of this meta-analysis are true even when the number of subjects per moderator variable is not always adequate.

The inclusion of studies using exclusively competitive athletes probably introduced a bias in our meta-analysis. In a context where no one wants to take the chance of a substandard performance, it is likely that researchers are studying tapering strategies that have been proved to be successful, either scientifically or empirically, thus leading to a circular thinking. Innovative tapering designs should be tested to have a comprehensive understanding of the adaptive response to the decrease in training load. New developments in mathematical modeling offer an interesting alternative (6,7,67). As underscored by Thomas and Busso (67), mathematical simulations provide a convenient technique to determine the combination of reduction in training load and its duration that will maximize performance, simply by changing the pattern of training. This objective tool could be used

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to propose potentially successful innovative tapering designs that will be tested with competitive athletes afterwards.

CONCLUSION

The purpose of this investigation was to assess the effects of the alterations of taper components on performance in competitive athletes, through a meta-analysis of the literature. A 2-wk taper during which training volume is exponentially reduced by 41–60% without altering training intensity or frequency appears to be the most efficient strategy to maximize performance gains. Alternative tapering designs could also have a beneficial effect on performance of individual athletes, but more pronounced interindividual differences may be expected. This meta-analysis provides a framework that can be useful for athletes, coaches and sport scientists to optimize their tapering strategy. Future investigations should evaluate alternative and innovative tapering strategies exclusive to those included in this meta-analysis, which could prove to provide further performance benefits to athletes, as suggested by recent mathematical modeling simulations.

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