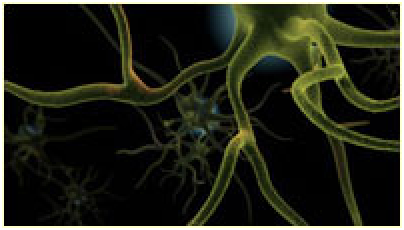
A Scientific Application of Tapering to Maximize Performance for the Elite Athlete Part I



Researched and Composed by Jacob Wilson, BSc. (Hons), MSc. CSCS and Gabriel “Venom” Wilson (Hons), CSCS

Abstract

Part I of this series discussed the two factor theory of human performance, which states that performance is the difference between fitness and fatigue. That paper reviewed the current dominant basis for the taper, which involves a systematic decrease in total load to facilitate a physiological peak in performance. Total load can be described as a combination intensity, volume, and frequency. Therefore, it is the manipulation of these variables that will ultimately determine the outcome of a peak cycle. In this context, the purpose of this paper is to provide a comprehensive analysis of all relevant studies on the tapering protocol.

Introduction

Tapering (also called a regeneration cycle) involves a systematic decrease in overload to facilitate a physiologic fitness peak (Plowman and Smith, 2003). The goal is to remove fatigue, emphasize relaxation, and prevent overtraining. Most athletes fear that by tapering for more than a day or so, they will have a detraining effect. But this could not be farther from the truth.

Studies show that if intensity is maintained, while training volume and frequency are reduced, physiological adaptations are retained and performance is equaled, or improved. However, if intensity is decreased, results will suffer. This is why injured athletes, for example, would have a very difficult time maintaining gains. It is often difficult to maintain a high intensity under that set of circumstances.

Overload occurs when the magnitude of training load is above habitual levels. It can come in the form of a greater intensity, increased volume, or increased frequency—and each should be utilized. However, intensity appears to be the factor, which causes the greatest regression in the individual when lowered. That is, both frequency and volume are vital when overloading the system, but intensity appears to be more important when maintaining adaptations.

The following section will analyze these three aspects of overload, and present their proper applications to tapering.

Training Intensity, Volume, and Frequency

As stated, the key to maintaining performance during a taper is intensity. The word intensity, however, is ambiguous. In this case, it refers to percent of a one repetition maximal performance—such as a one repetition maximum, VO2 max, or heart rate maximum. What this means is that the participant must maintain their original intensity, in order to preserve fitness gains. Therefore, if an individual usually lifts at 6 repetitions for squats, they should maintain that lift during their taper. As an illustration, if on most weeks the individual squats 400 pounds for a rep scheme of 10, 8, 6, and they decide to drop this down to 300 during their taper, they would lose a significant amount of adaptations, and very rapidly.

Briefly, volume can be defined as sets multiplied by repetitions; when the objective task requires the participant to carry his or her own body over long distances, such as in swimming, bicycling, and running, then volume can be defined as the distance covered, or duration of the activity.

Frequency can be defined as the number of training sessions over a period of time. These terms will be discussed in-depth further on under the heading "Mass vs. Distributed Practice."

In one of the greatest contributions to the body of science, Hickson et al. (1981, 1982, and 1985), performed a 3 part study, in which he investigated the effects of intensity, volume, and frequency on endurance time, VO2 max, and left ventricle mass during a tapering cycle. 12 participants performed a 10 week intense interval training program, consisting of bicycling and running for 40 minutes, 6 days per week, followed by a 15 week reduction in frequency, volume, or intensity. In the reduced frequency group, training was reduced from 6 days per week, to 2-4 days per week, while intensity and volume were maintained; training induced improvements were maintained. Further, when volume was decreased from 40 minutes to 26, while maintaining intensity and frequency, performance was also maintained; however, a reduction to 13 minutes decreased performance in long duration endurance time, though all other performance measurements were maintained. Now, here is the interesting part: when intensity was reduced by 1/3 to 2/3rds, while maintaining frequency and volume, performance was not maintained. These studies clearly demonstrate the importance of intensity for maintaining performance gains.

Sheply et al. (1992) investigated the physiological and performance effects of a 7-day training taper by highly trained middle-distance runners. After 8 weeks of training, nine male middle-distance runners were randomly assigned to one of three different 7-day tapers: a high-intensity, low-volume taper (HIT); a low-intensity, moderate-volume taper (LIT); or a rest-only taper (ROT). Participants performed all three tapers: after the first taper, participants resumed training for 4 weeks and performed a second taper, and then resumed training for 4 weeks, and completed the remaining taper, while maintaining a consistent diet throughout the experiment. Results showed that running time to fatigue increased significantly after HIT (+22%), as well as muscle glycogen concentrations, total blood volume, and citrate synthase activity. The LIT protocol showed no significant increases in performance, while the ROT protocol showed a significant increase in muscle glycogen; but, conversely, a significant decrease in citrate synthase activity, and blood volume.

The authors postulated that the increase in blood volume was due to both maintained adaptations in the HIT group, as well as decreased volume, which would decrease the amount of red blood cell destruction. To elaborate, during exercise, the constant pounding of tissue, such as the feet during running, results in the destruction of red blood cells. This phenomenon is known as Foot Strike Hemolysis, or pseudo anemia—which is a low blood count, but maintenance of iron levels. In this case, blood will rise back quickly within 2-weeks of decreased exercise volume (Inouye, 2005). Concerning muscle glycogen stores, they propose that the HIT group had adequate rest to synthesize glycogen through decreased volume. The evidence of this experiment, therefore, suggests that decreased volume appears to allow sufficient recovery and supercompensation to occur; whereas, the brief high-intensity training session provides enough stimulus to prevent detraining.

Concerning enhanced fluid volume from the HIT protocol, results show that as exercise intensity increases, hormones that conserve water increase (Hickson et al. 1982). For instance, Convertino et al. (1981) investigated the responses of plasma volume, osmolarity, sodium concentrations, vasopressin, and renin activity to graded exercise work loads, and the interrelationships between these responses. To elaborate, a graded exercise test is when an athlete progressively increases intensity after each time steady state is reached, until the desired level is reached. For more information on sodium, osmolarity, and its effects on plasma volume, refer to Venom (2004) Sodium - A comprehensive Analysis.

Essentially, these hormones would promote fluid retention, among other effects. To examine this, 15 male participants performed 3 levels of cycle ergometer tasks at 100, 175, and 225 watts (W; one watt=6.12 kgm). It was found that plasma volume decreased proportional to work intensity. Plasma volume decreased by 3.7% at 100 W, 8.8% at 175 W, and 12.4% at 225 W. Plasma sodium concentration, osmolarity, renin, and vasopressin increased proportionally with work intensity, with a threshold at 40% VO2 max for significant changes to occur. Further, there was a high correlation between plasma volume and sodium (.89) and osmolarity (.99); while vasopressin was significantly correlated with sodium (.86) and osmolarity (.83).

Thus, the results of this experiment suggest that vasopressin is a primary factor for fluid and electrolyte regulation during exercise, as it is highly correlated with hyper-osmolarity, induced by a decrease in plasma volume. Additionally, as exercise intensity increases, osmolality, sodium, vasopressin, and renin are increased proportionally, with a threshold of 40% VO2 max. Exercise intensity above 40% VO2 max is required to change plasma osmolality and, thus, stimulate significant vasopressin release. Concerning renin, it is well documented that the sympathetic nervous system stimulates its release (Davis and Freeman, 1976; Donald, 1979); therefore, the authors proposed that increased sympathetic activity was the primary stimulus for its release. For instance, Kotchen et al. used graded work loads of 40, 70, and 100% VO2 max to examine the responses of renin, norepinephrine, and epinephrine. Renin activity increased linearly with work load and became significantly elevated after exercise at 70 and 100% VO2 max, but not after 40% VO2. Further, Wilson (2004) demonstrated that as exercise intensity increases, sympathetic nerve activity rises (refer to, Exercise Endocrinology Principles and Catecholamines), supporting this hypothesis.

These results fit well into the two-factor model of human performance. The fitness was manifested with an increase in various hormones conducive to increased blood volume. However, these effects were masked by fatigue manifested in the form of dehydration. Therefore, a period of rest would allow the fatigue (dehydration) to dissipate, and the fitness (increased water reserving hormones) to be manifested. The net result would be a continued increase in blood volume, without the negative influence of dehydration! In this context, the major influence of training intensity on the retention or improvement of training-induced adaptations could be explained by its role in the regulation of concentrations and activities of fluid retention hormones.

Moving on, after undergoing a vigorous stretching program for 30 days, 3 days a week, results showed that reducing this to one session per week, while training at the same intensity, maintained improved muscle flexibility (Walin et al., 1985).

Trappe, Costill, and Thomas (2000) performed an excellent experiment to examine the changes in whole muscle function and single cell contractile properties of Type I and II muscle fibers from the deltoid muscle of highly trained swimmers before and after a 21-day reduction in training volume, while maintaining their intensity. Results found that whole muscle power increased 17% and 13% on the swim bench and swim power tests respectively; Type IIa fibers were 11% larger; Peak force increased significantly in fast twitch fibers; and shortening velocity was 32% and 67% faster in the Type I and IIa fibers, respectively. Further, a previous study by Trappe et al. (1998) of the same protocol, showed almost identical results. This may partially explain the mechanisms behind previous studies on tapering, such as Costill, King, and Thomas (1985), in which they found that whole muscle power measured on an isokinetic swim bench (this is similar to an isotonic contraction, in which the length of the muscle changes (shortens and lengthens); however, a machine sets a constant speed for the participant) improved 18%, and swim power increased 25% during a swimming taper.

Mujika et al. (2000) examined several physiological and performance responses to a 6-day taper, and the influence of training intensity and volume on these responses. Participants consisted of eight male middle-distance runners. After 15 weeks of training, they were randomly assigned to moderate volume taper (MVT, N = 4) or a low volume taper (LVT, N = 4), of either a 50% or a 75% progressive reduction in pre-taper low intensity continuous training (LICT) and high intensity interval training (HIIT). Blood samples were obtained and 800-m running performance was measured before and after taper. The LICT portion of the taper appeared to stimulate erythropoiesis (red blood cell formation), but increasing the volume of this type of training was associated with high plasma creatine kinase levels and lowered lymphocyte count and total testosterone. While the HIIT portion of the taper was non-significantly (r=.68) correlated with free circulating testosterone. Lastly, the 800 meter run performance was significantly better with a 75% reduction, rather than a 50% reduction in volume.

Houmand et al. (1994) investigated if a 7-day taper could improve distance running performance. 8 runners participated in a run taper consisting of high-intensity intervals and an 85% reduction in training volume, while controls continued their normal routine. Results showed a 3% decrease in 5-km time, a significant decrease ($P < 0.01$) in submaximal oxygen consumption (6%), and calculated caloric expenditure (7%) at a running speed eliciting 80% of VO2 max during the run taper.

Johns et al. (1992) studied competitive swimmers progressively reducing training volume prior to an important competition in an effort to improve performance capabilities. Twelve intercollegiate swimmers were tested before and after taper in preparation for their season-ending meet. Power during a tethered sprint swim increased significantly ($P < 0.05$) by approximately 5% following the taper. Performance gains were maintained in distance per stroke, oxygen consumption, and post-exercise blood lactate level following the taper.

Martin et al. (1994) investigated whether changes in isokinetic leg strength parallel changes in cycling performance during a six-week high-intensity aerobic interval training program and a subsequent two-week taper. Significant improvements in cycling performance (8%) and QUAD strength (8-9%) were found.

Another study—which should be of great interest to the reader—was composed on weight lifters. Gibala, MacDougall, and Sale (1994) examined voluntary strength and evoked contractile properties of the elbow flexors over a 10 day rest only (ROT) and a 10 day reduced volume taper (RVT) in 8 resistance trained males. The authors found that resistance-trained athletes can improve low velocity concentric strength by greatly reducing training volume, but maintaining training intensity.

Mujika et al. (1998) investigated the effects of 12 weeks of intense training and 4 weeks of tapering on plasma hormone concentrations and competition performance in a group of highly trained swimmers. Performance increased during the taper ($P < 0.01$) and this was correlated with changes in the testosterone cortisol ratio. Neary, Gaul, and Smith (1997) further examined the effects of a taper on urinary free cortisol and serum testosterone in 8 (2 female, 6 male) elite runners. Results found that mean urinary cortisol was significantly reduced; moreover, 4 of the 6 males had biologically significant increases in serum testosterone.

Neary et al. (1992) investigated the influence of tapering on metabolic and performance parameters in endurance cyclists. Participants cycled 5 days a week, 60 minutes per session, for 8 weeks. After, they either performed a taper for 4 days ($n = 7$), 8 days ($n = 6$), 4 days of just rest (control; $n = 6$), or no taper (continued training; $n = 6$). Beta-hydroxyacyl CoA dehydrogenase (key enzymes in the oxidation of fatty acids and in mitochondrial fatty acid synthesis) and carnitine palmityltransferase (an enzyme that reversibly forms acylcarnitines and coenzyme A from carnitine and acylcoenzyme A; important for fat oxidation) decreased 25% (P less than 0.05) and 26% respectively, in the 4 day rest taper. Muscle glycogen levels were higher in all tapering groups, except the no taper group. Power output at ventilation threshold was significantly increased in the 4 day and 8 day tapers, but not in the non taper group.

Another study (Margaritis et al., 2003) found that implementing a taper and antioxidant supplementation at nutritional doses (best results coming from a combination of both) for triathletes, reinforced antioxidant status response to exercise, with an effect on exercise-induced oxidative stress, and no effect on oxidative damage. Vollaard et al. (2003) further investigated the oxidative stress response to overloaded training and tapering. Results found that during the high volume training period, levels of oxidatively modified heme (+4 %) and oxidized glutathione increased (+13.5%); while there was a decrease in reduced glutathione (-13.5%). Conversely, tapering significantly increased performance (+4.7%), and was associated with an increase in resting reduced glutathione levels (+8.8).

Therefore, tapering may enhance the antioxidant defense system. For a complete explanation on all the terms discussed here, refer to Knowlden (2004), Role of Antioxidant Supplementation in Response to Exercise Induced Oxidative Stress.

Neary et al. (2003) examined the effects of different 7-day taper protocols on simulated 20-km time trials following 3 weeks of training. 11 male cyclists were randomly assigned to one of three tapers in which training volume was reduced by 30% (n = 5), 50% (n = 6), or 80% (n = 6) of baseline training with intensity (85% VO2 max) maintained. Results revealed a significant (5.4%) improvement in 20-km time trials performance in the 50% volume reduction protocol with concomitant increases in VO2 and O2 pulse. No significant differences were found in the 30% or 80% protocols. This study appears contradictory to previous studies which demonstrated that an 85% reduction in training volume during a 7 day taper, for instance, increased performance gains (Houmand et al., 1994). It may be that the accumulated fatigue of training for 3 weeks did not require an 80% reduction in training volume during the taper; and doing so, therefore, led to suboptimal results.

In another study by Neary et al. (2004) results found significant ($P \leq 0.05$) reductions in salivary cortisol pre-to post-taper. Incidentally, salivary cortisol has recently been used to monitor recovery from the physiological stress imposed by exercise training (Neary et al., 2004).

Another marker of the overtraining syndrome are catecholamines. For instance, Hooper (1993) found that plasma norepinephrine and epinephrine concentrations were significantly correlated with swim training volume. Additionally, epinephrine levels were significantly lower after the competition compared with values early in the season and shortly before competition. Symptoms of the overtraining syndrome were identified in three of the swimmers, based on performance decrements and high, prolonged levels of fatigue. In these three swimmers, norepinephrine levels tended to be higher than those of the other swimmers from mid-season onward and were significantly reduced during tapering. In this context, Shannon et al. (2004) evaluated the catecholamine response to reduced training loads. It was found that dopamine (a precursor to norepinephrine and epinephrine) correlated with training load changes, suggesting that reduced training during a taper is an effective way to reduce stress.

Contreras et al. (2003) investigated the effects of a 14 day taper on running economy in 10 well trained distance runners, after 20 weeks of training. Economy is the oxygen cost of walking or running at various speeds. For example, if two runners have the same VO2 max, and runner A beats runner B every race, this may be because he could work at a higher percent VO2 max for a longer amount of time—which means he had a higher economy. Consequently, results found a significant increase in running economy after the taper.

Martin and Andersen (2000) performed a fascinating study, in which they investigated the heart rate-perceived exertion (HR-RPE) relationship under conditions of high-intensity training and taper. Concerning RPE, it is a numerical scale invented by the scientist Borg ranging from 6 to 20—6 being minimal effort and 20 being maximum effort. Several predictions have quite accurately been made from this scale. For instance, an increased RPE at a given workload is highly correlated to glycogen depletion (Wilson, 2003, Pre Contest Week - An In Depth Analysis). Participants consisted of collegiate cyclists (n=11). They performed six weeks of high-intensity interval training, followed by a one-week taper. Results found The HR-RPE relationship changed over the course of the training with greater RPEs for a given HR at the end of the training compared to the beginning. Those individuals who reported higher RPEs for lower HRs were more likely to have better performance responses to taper (r=0.72). Therefore, the HR-RPE ratio may be a good indicator of overtraining. Athletes may use this measurement to monitor accumulated fatigue, and perhaps consider a taper if higher RPE's are found for a given HR. This increase in rate of perceived exertion at a given heart rate as a consequence of overload, could be the result of depleted glycogen stores, lowered blood volume, among other manifestations of fatigue. The taper would effectively dissipate this, optimizing the fitness gains achieved during training.

Fukuba et al. (1999) investigated the effects of a taper on lactic acid clearance and performance. It was found that the criterion performance improved during each taper period; peak blood lactate levels were highest after the taper—this may be attributed to an increase in the rate of glycolysis and muscle glycogen content. Further, lactate clearance was improved.

Tapering is also associated with beneficial psychological enhancements. These include: reduced perception of effort, several reduced mood disturbances, reduced rate of perceived exertion, and increased vigor (Hooper et al., 1999; Morgan et al., 1987; Raglin et al., 1996). Additionally, quality of sleep has been found to increase in competitive swimmers following a taper (Taylor et al., 1997).

Training Volume and Frequency

It should now be evidently clear to the reader that intensity must be maintained during a taper to maintain exercise induced performance gains. However, volume and frequency should significantly be reduced in order to dissipate the reactive inhibition. The following section will closely analyze the magnitude of this reduction; particular emphasis will be placed on training frequency.

As previously reported, Hickson et al. (1981) found that a decrease in training frequency by 33-66% over 15 weeks maintained exercise-induced increases in maximum oxygen uptake. Johns et al. (1992) found increased power and performance in competitive swimmers who reduced training frequency by 50% during 10 and 14 day tapers. And Dressendorfer et al. (2002) observed a significant improvement in a 20-km cycling time trial after a 50% reduction in training frequency during a 10-d taper.

It is clear, therefore, that frequency can be significantly reduced during a taper. However, the question remains on the optimal combination for reduction of both training volume *and* frequency.

Houmard et al. (1990; a) investigated this query with endurance runners during a 3-week reduction in training volume and frequency. Participants consisted of ten well-conditioned runners who were monitored for 4 weeks while training at their normal weekly training distance. Participants reduced volume by 70% and decreased training frequency from 6 days a week, to 5 (a 17% reduction). Time to exhaustion during the VO2 max tests increased ($P < 0.05$) by 9.5% at week 3 of the taper.

Houmand et al. (1990; b) again investigated the effects of reduced training volume and frequency; but this time on testosterone, cortisol, and creatine kinase levels in male distance runners. Participants consisted of 10 male runners. Participants performed 4 weeks of normal training, followed by a 3-week taper. Volume was reduced by 70%, and training frequency was reduced from 6 days a week, to 5 (17%), while maintaining intensity. Testosterone levels were lower and cortisol levels higher after the 4 week training period. However, the taper did not alter these levels. Conversely, creatine kinase was elevated during the 4 week training period, but significantly reduced ($p<.001$) following the taper.

Graves et al. (1998) found that reducing volume and frequency during a taper was also advantageous for strength athletes.

Mujika et al. (2002) found conflicting results with the aforementioned studies, however. After 18 weeks of training, 9 male middle-distance runners were assigned to a high frequency taper ($n = 5$) or a moderate frequency taper ($n = 4$), consisting of training daily or resting every third day of the taper. Performance improved significantly after the high frequency taper, but not after the moderate frequency taper. Moreover, various white blood cells, total testosterone, and lactic acid peak all significantly increased with the high frequency taper but not the moderate frequency protocol. The results of this study suggest that training daily during a 6-day taper results in significant performance gains; whereas, resting every third day does not.

More studies need to be performed on this aspect of tapering. However, based on the current scientific body of evidence, the general consensus among the scientific community is to significantly reduce volume, while only slightly reducing frequency during a taper (Houmard, 1991; Houmard and Johns, 1999; Mujika et al., 2003). In fact, Mujika et al. (2003), who performed a meta analysis on tapering, concluded that benefits from a taper are best attained by "maintaining training intensity, reducing the training volume (up to 60-90%) and slightly reducing training frequency (no more than 20%)."

Perhaps the most powerful evidence in support of a high frequency, low volume taper, is the learning variable known as "mass vs. distributed practice". These concepts will be discussed subsequently.

Mass vs. Distributed Practice

Training frequency can be defined as the total number of training sessions performed for a given skill, task, or body part within a given time period. The time measured is typically a week in length (Mclester, 2000). Training volume can be defined as the total work performed in a given time period. Work done on an object is calculated by multiplying the force applied to the object over the distance the object was moved. Typically, work is not directly measured; and therefore, volume can be approximated by a concept known as total repetitions (Baker et al., 1994). Total repetitions are calculated as follows:

Total Sets * Repetitions

When the objective task requires the participant to carry his or her own body over long distances, such as in swimming, bicycling, and running, then volume can be defined as the distance covered, or duration of the activity (Hickson et al., 1982).

If volume is analyzed over a one week period, as opposed to a single training session, then frequency of training will have a direct influence on this training variable. Therefore, lowering weekly frequency can also lower weekly volume. In this context, an optimal combination of frequency and training volume should be established.

The earliest studies to examine such a combination entailed massed verses distributed practice. Massed practice can be defined as practice in which the work time period is longer than the rest time period (Schmidt and Lee, 1999). Distributed practice can be defined as practice in which the rest period is longer than the work period (Schmidt and Lee, 1999). In weight training, 1 minute sets, with 20 seconds of rest would be massed scheduling; whereas, 30 seconds of work followed by 1 minute of rest would entail a distributed practice. Hull (1943, 1952) inspired the examination of this phenomenon (See Wilson, 2005 on Hull's contribution to performance for a review) and found that given equal trials, distributed practice for both cognitive and motor tasks produced better performance and skill acquisition than massed practice (Wilson, 2005; Schmidt and Lee, 1999).

The relative distribution of time also has been found to have an effect on skill acquisition. For example, in a classic study, Archer (1916) found that if a skill is performed for a total of 34 days, then a group of subjects who performed the skill 5 days a week for 7 weeks, did not increase performance to the same extent that participants who performed the same total of 34 days spread over 12 weeks, at a frequency of 3 days a week.

In this context, Hakkinen and Kallinen (1994) investigated the effect of distribution of volume on neuromuscular adaptations in 10 strength athletes. The athletes participated in two 3 week conditions. In both conditions volume was held constant; however, in condition one the volume was distributed in one session. In condition two, the volume was divided into two sessions, at separate times in the same day. No significant strength or cross sectional area gains were found in condition one. However, in condition two, both an increase in strength and cross sectional area were found. They concluded that 'The present results with female athletes suggest that the distribution of the volume of intensive strength training into smaller units, such as two daily sessions, may create more optimal conditions not only for muscular hypertrophy but by producing effective training stimuli especially for the nervous system. These kinds of training conditions may lead to further strength development in athletes being greater than obtained during "normal" strength training of the same duration.'

In another study Mclester et al. (2000) investigated a comparison of 1 day and 3 days per week with equal volume resistance training in experienced subjects. Participants trained various upper and lower body exercises over 12 weeks. In group one, 3 sets per exercise were performed in one day during the week. In group two, one set was performed on three separate days. It was found that the higher frequency group gained 38 % more strength than the lower frequency condition, suggesting that higher frequency, even when volume is held constant, is superior for strength gains. Further, greater lean body mass gains were found in the higher frequency than lower frequency group.

Therefore, the current authors propose that reducing volume (Total Sets * Repetitions) and maintaining a higher frequency during a taper, would elicit optimal results. Practical applications will be discussed further on.

Type of Taper

A taper can be performed four ways:

- Step taper—load is immediately dropped. For example, if the athlete plans to reduce volume down to 30%, this would be done on the first day of the taper, and then maintained for the duration of the taper.
- Linear taper—load is progressively reduced in a linear fashion. For example, lowering volume 10% everyday until the desired reduction is achieved.
- Exponential (slow decay) taper—load is non-linearly reduced, with a slow decay rate.
- Exponential (fast decay) taper—load is non-linearly reduced, with a fast decay rate.

Zarkadas, Carter, and Banister (1995; Banister, Carter, and Zarkadas, 1999) investigated the nature of taper required to optimize performance in Ironman triathletes. Participants consisted of eleven triathletes. Participants trained for three months, interspersed with two tapers: 10 days (taper 1) and 13 days 6 weeks later (taper 2). For the first taper, participants in group one reduced training volume by 50% in an exponential fashion; results found a 46 second (4%) improvement in their 5 km criterion run time and a 5% increase in maximal ramp power output above the same measurement at the beginning of taper. A 30% step reduction in training volume in the second group did not result in any significant improvement in physical performance on the same measures. Another group in the second taper reduced volume exponentially using either a slow decay (high volume) or fast decay rate (low volume). Maximal ramp power increased significantly by 8% only in the fast decay taper. VO2 max increased progressively during the fast decay group; additionally, anaerobic threshold was also observed to increase from 70.9% to 74.9% of a subject's maximal oxygen uptake during the fast decay taper. The authors concluded that an exponential taper is superior to a step taper, and that a fast decay exponential taper is superior to a slow decay exponential taper.

Very few studies have been done on this topic, and the studies that have been done have inherit flaws—including this one. During the aforementioned taper, it did not just compare decay rate, it compared the effect of total reduced volume on performance. That is, a step taper had significantly higher volumes than an exponential taper; and the slow exponential taper had significantly higher volumes than the fast exponential taper. The results, therefore, may suggest that a low volume taper is superior to a high volume taper—not necessarily that an exponential fast decay taper is optimal. Studies need to be done in which step and exponential tapers are compared with equal amounts of reduction in volume.

In conclusion, there is an inadequate amount of studies on this topic; and the few studies that have been done are flawed. Thus, the current authors cannot concretely recommend the exclusive use of a step, linear, or exponential taper.

Training Specificity

One important concept the athlete must apply during a taper is the specificity hypothesis. Here is a quote which explains this concept (Wilson and Wilson, 2004), Energetic Transference Occurring in the Biosphere Part III:

> Training adaptations will be viewed as specific to imposed demands placed on participants. Henry (1950) proposed the specificity hypothesis, suggesting that the attributes that underlie an activity are specific to that activity and not transferable (task-specific). Sawyer et al. (2002) suggests that an attribute is the underlying capacity within an individual, which allows for the expression of skill (these are presently viewed as genetically predisposed and typically unaffected by practice). The statistical evidence highly supports these concepts (Sawyer et al., 2002).
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> It is important to understand that greater transfer, even at the level of energy systems, will be realized when training is specific to the criterion task. For example, riding the stationary bike will produce cardiovascular adaptations, but they will not enhance the extraction of the extra oxygen delivered when training the upper extremities (known as arterial venous difference). Maximum oxygen uptake by an organ is described by Fick's principle. Fick's principle states that the amount of oxygen utilized by a tissue is defined as the product of blood traveling to that tissue and the extraction of the oxygen delivered. Therefore, adaptations from a physiological level occur centrally, peripherally, and at the cellular level itself. These adaptations occur through increased and specific capillarization, increased mitochondria number, as well as specific enzymatic activity.
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> Therefore if a participant seeks to increase mitochondrial density, and therefore enhance the arterial venous difference, they will need to train the upper extremities in an aerobic fashion.
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> Further, it is important to also understand that these adaptations are also specific to the actual task itself. Riding a bike while standing will activate the motor neuronal pool, as well as various other musculatures, in a different manner than riding a bike while seated will. Moreover, running on a horizontal surface will activate musculature in a different pattern than running on an incline. It is for this reason that coaches will benefit by training their athletes for the event that they will have to face. If a cross-country team is used to running horizontal, and then are faced with running on an incline type of hilly surface, they will be seriously under matched. Therefore, the following recommendations and adaptations will be heightened when done specific to the task.

Therefore, in order to maintain training induced improvements, the athlete must train specific to the criterion task. That is, if you are a swimmer, you need to swim during a taper. Moreover, exercises within a sport also are very specific. For instance, if an athlete plans to maintain or improve his or her squat, bench press, and dead lift during a taper, the athlete would need to practice all three lifts.

Summary

The taper involves a systematic decrease in overload to facilitate a physiologic fitness peak (Plowman and Smith, 2003). The goal is to remove fatigue, emphasize relaxation, and prevent overtraining. In this context, studies pertaining to frequency, volume, and intensity were reviewed. For practical implications of these variables, the reader is suggested to review part three of this series.

Jacob Wilson
President Abcbodybuilding / The Journal of HYPERplasia Research

jwilson@abcbodybuilding.com

Gabriel “Venom” Wilson
Executive of Bioenergetic Research
Venom@abcbodybuilding.com

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