TrainingPeaks Performance Manager – a New Tool for Training Analysis

BY CHARLES HOWE

Just how much insightful analysis it actually yields can vary widely, however, most all serious competitive athletes keep a training log or diary, in which various workout information is dutifully recorded. Initially, this often goes no further than keeping track of such training variables as duration and intensity (the latter either as perceived exertion or heart rate), then perhaps charting/planning training volume, in miles per week. This is a useful start, and better than nothing, but it becomes apparent quite soon that 200 miles of relatively steady-state base training on the flat are less taxing, and require less recovery time, than an equivalent distance of spirited group rides over hilly-to-mountainous terrain; tracking duration (hours) instead of miles offers only modest improvement in quantifying the stress imposed by a training schedule.

With the advent of on-bike power measuring systems, it became possible to factor intensity into training volume, and thereby calculate training load for a given period:

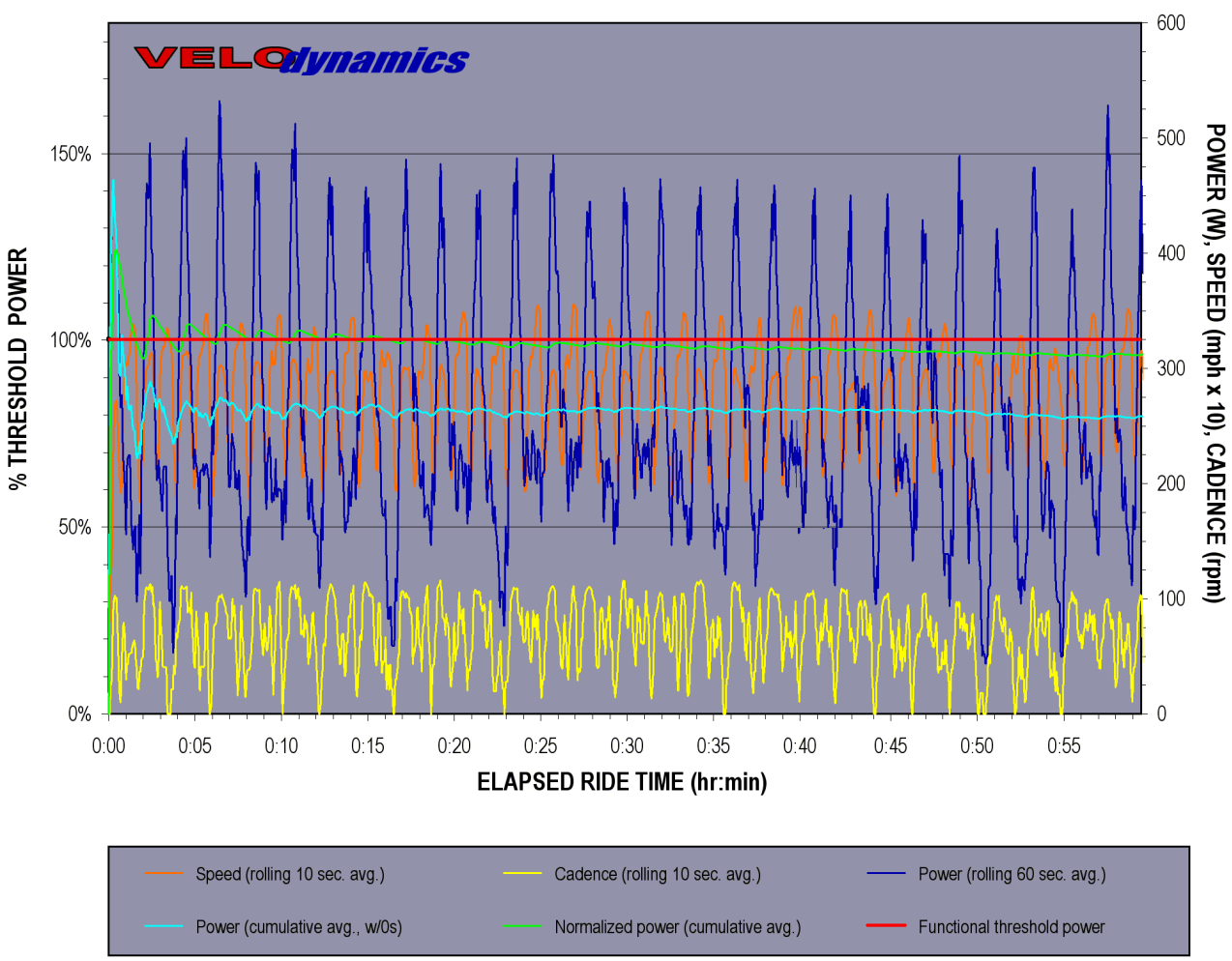
total duration for period in seconds (s) × average intensity in Watts (W) ÷ 1,000

= training load, or work output in kilojoules (kJ)

It soon becomes clear, however (as coach Dave Harris put it), that "not all kiloJoules are created equal," e.g., a 6,500 kJ week of off-season training is far less stressful than the same amount of work performed during a week of road and criterium racing, where variations in power output are much wider, more frequent, and more rapid.

To correct for this so-called 'stochastic' nature of power output, Normalized Power (NP) and Training Stress Score (TSS) were created by Andrew Coggan, Ph.D., a widely-noted exercise physiologist and former Cat. 1 competitor. The former accounts for the fourth-order relationship between exercise intensity and blood lactate levels, which broadly reflects physiological strain, thus, the adjusted wattage value yielded by the NP algorithm much more closely indicates how hard high-variability efforts actually feel than average power. For instance, the rider reported that the following one-hour criterium (Figure 1) was raced very hard, and fatigue sensations/recovery time afterward felt very similar to a flat 60-minute time trial*. Sure enough, NP is almost exactly what he could sustain for a steady-state ride of the same duration, whereas average power was some 53 Watts (17%) less than NP.

*Average power for a 60-minute TT is called Functional Threshold Power, or FTP. Intensity Factor (IF) = NP/FTP.



RIDE SUMMARY	7/5/04	
Rider:	AWG	
Event:	Fitchburg CT	
Level - conditions:	4 FV	
Body mass:	73	kg
Functional threshold power:	325	W
(= 60 min TT power)	4.45	W/kg
	18.34	$W/kg^{0.67}$
Recording interval:	2.52	sec
Ride time:	0:59:31	h:m:s
Pedaling time:	0:46:42	h:m:s
Pedaling %:	78%	
Distance:	27.5	mi
Avg. speed:	27.7	mph
Avg. cadence:	68	rpm
Avg. power (w/coasting):	258	W
Avg. pedaling power:	330	W
Avg. normalized power:	312	W
Peak 1 min. avg. power:	389	W
Peak 5 min.avg. power:	307	W
Peak 20 min. avg. normalized power:	324	W
Aerobic continuity:	83%	
Intensity factor:	0.96	
% of threshold	80%	
Training stress score:	91	
NOTES:		

Figure 1. Power, speed, and cadence for a 60-minute criterium.

While exceptions appear occasionally, NP has proven to be quite reliable since being introduced in 2003, oftentimes exceeding Coggan's suggested guideline of ±5% accuracy in reproducing a wattage value that is interchangeable, at least in terms of perceived exertion/recovery (if not training effect), with the average power of a steady-state effort lasting the same duration.

Such a robust metric of intensity allowed Coggan to formulate a more realistic indicator of training stress, namely, Training Stress Score. Referenced to the effort of a 60-minute, flat-terrain time trial, which is set as 100 points, TSS describes the toll exacted by a given quantity of training much more accurately than work output, and therefore better predicts the time needed to recover. (Some users have noted, and taken exception with, the 'non-additivity' of TSS within a ride, i.e., the segments of some types of workout will add up to considerably less than the whole, however, most seem to find this effect to be negligible.) In any case, the following table and chart are meant to provide rough guidelines for recovery time, based on TSS:

Table 1. Approximate single-ride recovery time by Training Stress Score.

TSS (pts.)	LEVEL of STRESS INCURRED
<100	low (no recovery needed)
100-200	medium (recovery usually complete the following day)
200-300	high (1-2 days recovery likely needed)
300-400	very high (2 full days recovery needed)
>400	epic (several days recovery needed)

Estimated recovery times presuppose a fully rested condition beforehand; since fatigue is cumulative, a 300 pt. ride will feel more taxing if preceded by a 200 pt. effort the day prior.

"Complete recovery" means simply that you should be able to train productively (as opposed to needing a recovery ride or day off), not that you will feel completely fresh.

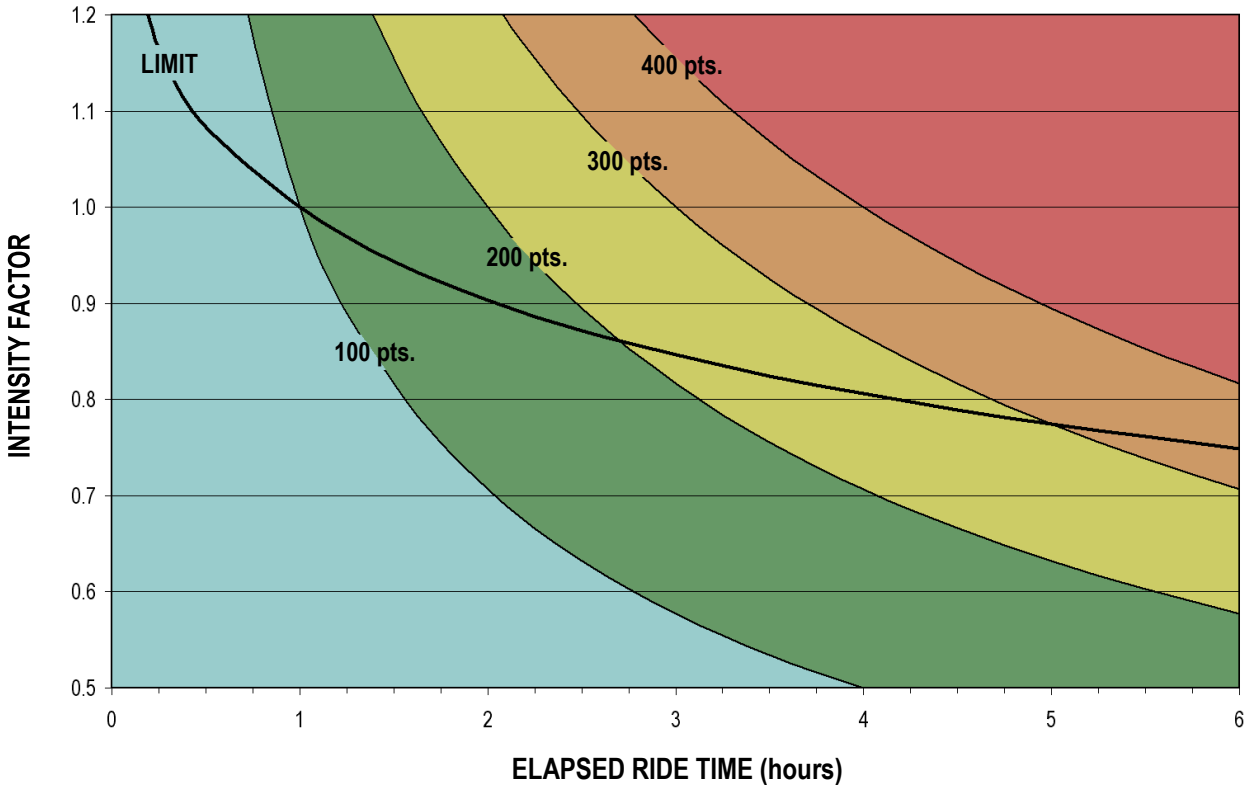


Figure 2. Training Stress Score levels by duration and intensity factor. (Note: the limit line was developed from the author's own data; the exact shape can vary considerably by individual.)

Right away, several individuals began using TSS to summarize, analyze, and plan their training schedules. Most notably, Dave Harris plotted 28, 14, 7, 5, and 3-day rolling averages to represent the continuum of long and short-term adaptation, while the author preferred to look at rolling totals for fewer intervals:

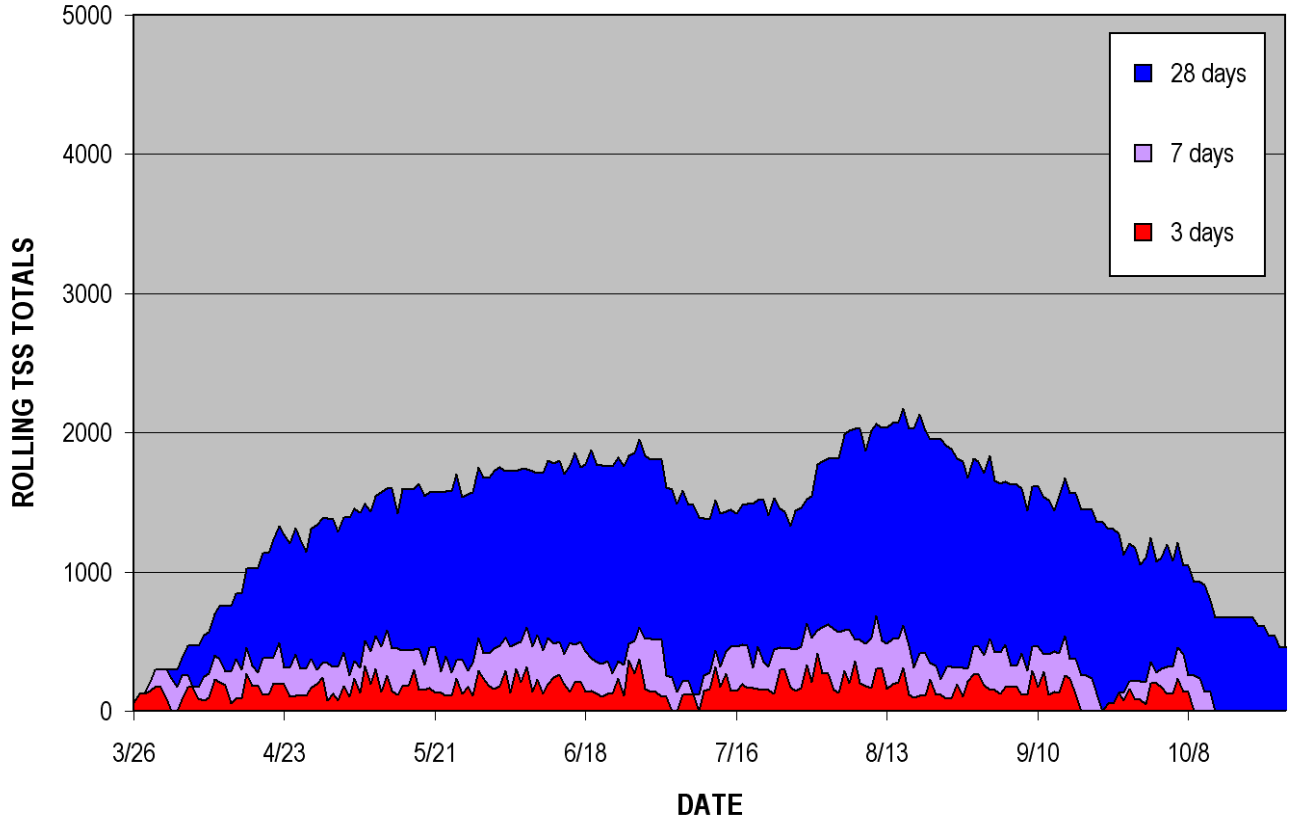


Figure 3. Rolling TSS totals for the author's 2005 season.

The effectiveness of both approaches is limited for the same two reasons: first, neither attempts to relate long- and short-term training loads to each other, and secondly, each uses an unweighted average, which assumes the most recent workout in the averaging interval has the same effect as the first.

TRAINING STRESS BALANCE

It remained for the ubiquitous Dr. Coggan* to work out a solution to both shortcomings. Drawing from numerous published studies of an impulse-response performance model, he expressed this relationship in simplified version as form = fitness + freshness, thus tying together long and short-term training loads (i.e., fitness and freshness, respectively), with form being the sum of the two. Alternatively, this can be stated as

Training Stress Balance (TSB) = Chronic Training Load (CTL) - Acute Training Load (ATL)

where TSS is used as input to obtain CTL and ATL (the "impulses"), but instead of a simple, unweighted average, this is accomplished using mono-exponentially decaying functions of previous workouts, which are calculated from time-constants (not half-lives) of 42 and 7 days, respectively, as derived from the scientific literature. Peak form, as indicated by TSB (the "response"), is just the right balance between exercise-induced physiological adaptations and the time required to optimize those changes. A more technical definition is a positive impulse-response relationship: a value calculated from the amount of training done ("fitness") and the recovery taken ("freshness").

*Consideration was given to *It's That Man Again* as an alternative title for this article, after the fondly-recalled British television programme that was popular during the Second World War, but the allusion seemed too obscure for American readers, and furthermore, 'That Man' actually referred to Adolf Hitler!

OK, SO IT'S BRILLIANTLY CONCEIVED . . . BUT DOES IT *WORK*?

In his initial forwarding of information to me, Dr. Coggan included examples of two individual pursuit competitors for whom it predicted peak performances very closely, along with these guidelines for interpretation:

1. overtraining is the result of a CTL that is too high for too long; most people seem able to tolerate a CTL of ~90 for extended periods, i.e., such a training load, if built slowly enough, generally does not lead to overtraining
2. overreaching results from an ATL that is too high and/or increases too rapidly
3. "training stagnation" is likely to occur when CTL plateaus for a period of 4-6 weeks without any change in training focus
4. undertraining, and/or failure to progress from year to year, is likely to result when the CTL that isn't high enough, or drops too much in the off-season
5. peaks in performance are likely to take place when CTL is high (but not too high) and ATL is low, so that the difference value (TSB) is positive, i.e., "form = fitness + freshness," but to get freshness, you must reduce training load, and hence give up some fitness.

I was skeptical that someone like me, for whom 7-8 hours a week represents a heavy training load, had much need for such sophisticated management of training load. Nonetheless, I was interested in applying TSB not only to my own diary, but also to several other continuous year-long blocks of data for some true competitive (Cat. 3) riders. Would TSB validate or discredit the training pattern that has seemed to work so well, namely, to make sure I felt fresh and recovered after (i.e., 36-48 hours) each key workout before attempting the next one? Somewhat to my surprise, TSB was *negative* for most every key workout and peak performance last year:

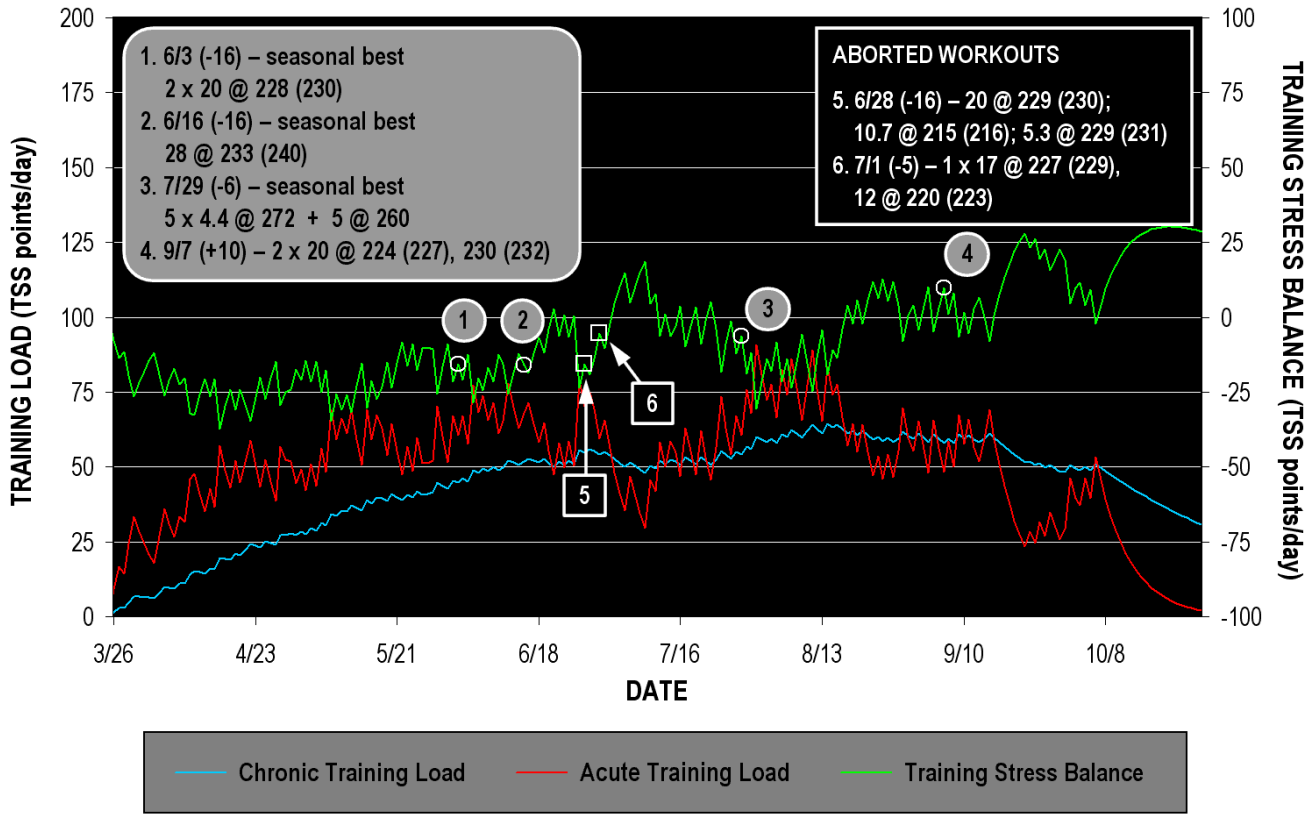


Figure 4. Training Stress Balance (TSB) for the author's 2005 season.

Upon closer examination, the reason for this becomes clear: a CTL of under 65 is not quite enough to balance out ATL 48 hours after the workouts I was doing. By contrast, this figure from the 2005 season of Scott Thor, a local Cat. 3 competitor whose CTL averaged ~80 throughout much of the year, shows that all but one of his peak 40 and 20-minute average race wattages were predicted by TSB:

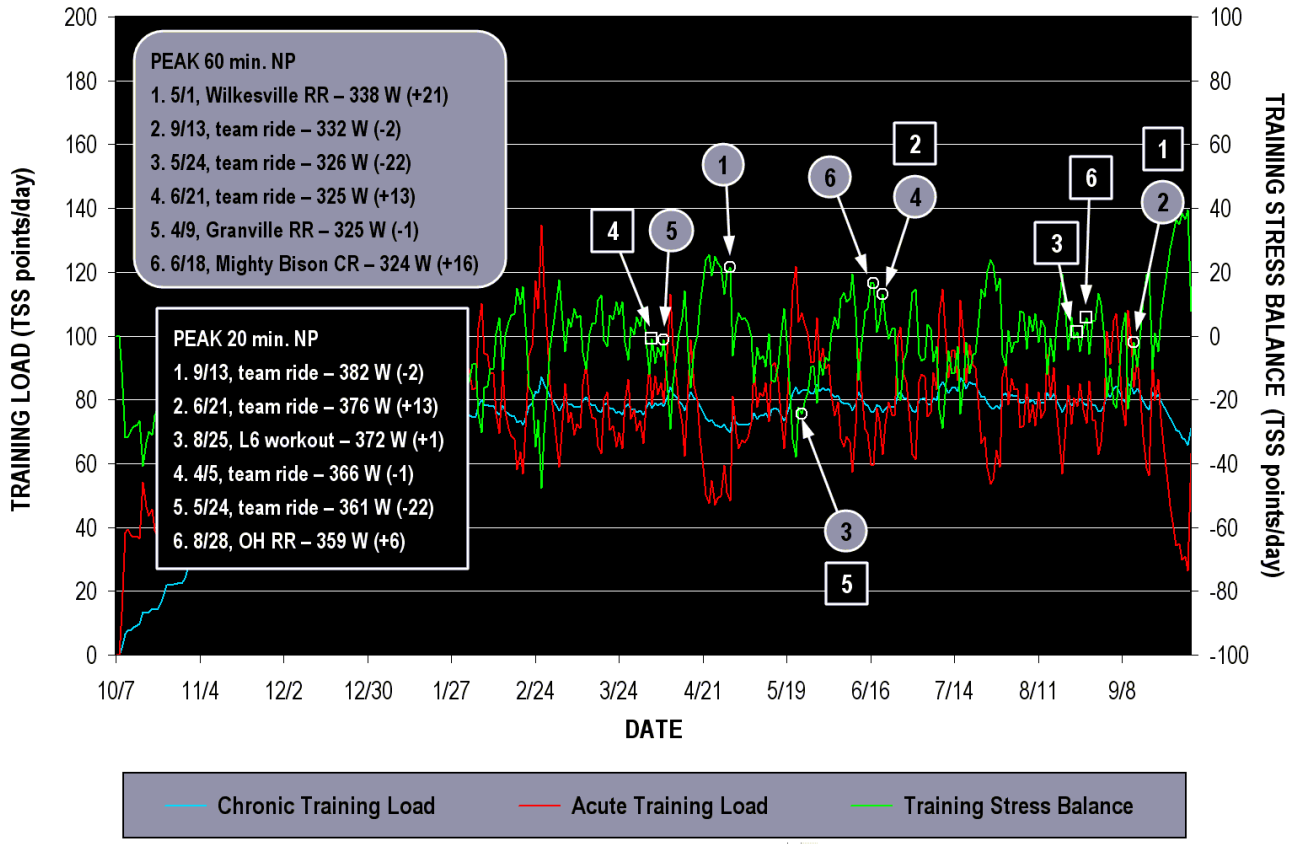


Figure 5. Training Stress Balance (TSB) for Scott Thor's 2005 season.

So does this mean that my sense of 'feel' was bad, and I should have been taking *more* rest? Not at all. Rather, as Dr. Coggan pointed out, individuals with lighter training loads (i.e., a CTL less than ~65) are subject to a small degree of chronic fatigue, and some studies have actually found that the second, negative impulse term does not predict performance any better in such cases, so CTL alone may suffice. As CTL rises to higher levels, and especially if the event being prepared for has significant anaerobic demands (e.g., an individual pursuit, prologue TT, points race, or *very* short criterium), TSB becomes more reliably indicative of form, although it need not be too positive on race day (+5 to +10) for most any road event.

This observation, along with recent discussion about the role of Level 3 training, as well as a growing interest in the methods of the late running coach Arthur Lydiard, all brought home the point that only so much intensity can be traded for volume before aerobic development (aka "training effect," or "metabolic fitness") starts to be compromised.

It was decided, therefore, to reconstitute my relatively low-volume, high-intensity regime (i.e., two 2 × 20 minute workouts per week, plus a 3-hour tempo ride on the weekend) as follows for 2006:

1. Transition from running to cycling exclusively would take place the last week of February, which was 19 weeks out from my goal event (the state time trial on June 25, 2006).

2. The first week would consist of only 3 one-hour Level 2 rides, with a fourth ride of the same duration/ intensity added in week 2. After that, most other training for the first 12 weeks would be Level 3, with a weekly Level 4 test, and one or two Level 1 recovery rides mixed in, as needed.
3. Starting in week 3, the intensity of each ride would be raised to Level 3, while duration would be structured so as to produce at most a 10% increase in TSS each week thereafter, until a maximum of ~650 points per week was reached in week 11 (first week of May). Weekly TSS would then be allowed to fall very gradually, although CTL would continue to increase until June 5, to a target value of ~80.
4. As a test of fitness and to set FTP, each week (commencing week 3) would begin with a Level 4 workout in 1 × 40-50 minute format on a standardized, flat-terrain course. From starting point of 205-210 Watts, this would increase by 5 W whenever the weekly test felt easy (most likely, every 2 weeks).
5. Seven weeks from the event, a Level 5 session would be added as the first workout of the week, and continue for 6 weeks, while Level 4 workouts would follow in sequence, going on as described before.
6. The last week would consist of one 60-minute and one 30-minute practice TT, then a 70-minute Level 2 ride the day before the targeted event.
7. Precision in hitting weekly TSS goals would be attempted by planning duration and Intensity Factor for all but the final workout each week, using past rides over somewhat standardized courses as a guide. For the last ride of the week – usually a 3-4 hour Level 3 ride on Sunday – these two variables would be adjusted up or down, as needed, in order to come as close as possible to the planned TSS total for the week.

I was hopeful that the greater volume of Level 3 training would make it possible to reclaim my performance level of June 2004, namely, 237 W average power (240 W NP) for 30 minutes, despite having aged from 46 to 48 years in the meantime. Unfortunately, as a hackneyed truism runs, 'the best laid plans of men and mice go astray,' and on April 24, I was struck from behind by a hit-and-run motorist, sustaining multiple fractures as a result, but despite this interrupted evaluation, I believe I learned several things:

1. Increasing TSS by 10% per week raises CTL 20-25 points every 4 weeks. This felt challenging but sustainable, although this belief could have been verified only in the uncompleted weeks of the training plan.
2. Although it might not be quite as accurate as expected in predicting performance so long as CTL remains low, TSB can be used to avoid increases in training load that occur too rapidly. Based on experience, it appears that recovery from a TSB of -50 is usually complete within 36-48 hours.
3. CTL does indeed seem to better reflect training load than a rolling total or average. For instance, just before being hit on April 24, my 28-day rolling TSS total was 2181, an all-time high for 2003-05, while CTL was only 54. By comparison, I felt considerably more tired last August 16, when these same totals were 2176 and 64, respectively, however, the level of perceived fatigue may have been affected by environmental heat stress, and a measure of long-term fatigue.

SOME FINAL COMMENTS VIA Q & A

Q: How can I use TSB, I mean, where can I get it?

A: TSB is part of TrainingPeaks Performance Manager, which is included in TrainingPeaks WKO+ (athlete and coach versions), an aftermarket package for powermeter data analysis. This is the culmination of a process begun by cycling coach Hunter Allen, Andrew Coggan, and software developer Kevin Williams in 2002:

1. create improved, power-based metrics for intensity and training stress (NP and TSS);
2. develop a software application to analyze rides based on TSS (TrainingPeaks);
3. determine the feasibility of TSS-based training plans;
4. develop an application that calculates and interprets training load from TSS data (the Performance Manager, which incorporates CTL, ATL, and TSB);

5. develop training plans that administer the exact amount of stress needed to create the right adaptation and peak at the desired time;
6. develop an application to create TSS-based training plans for the end-user;
7. publicize and teach the training system (*Training and Racing With a Power Meter*, from VeloPress).

Q: *OK, this is a great system and everything, but I'm not a pro who does nothing besides eat, sleep, and train – I have a full-time job and lots of stress in my life. You can't quantify those things, so you have to go by 'feel.'*

A: Quoting Dave Harris once again, "The body is like a Swiss watch, you just have to know how to wind it." Another comparison might be to a computer that responds as it is programmed. That said, stress from work and family, environmental heat, inadequate rest, etc., may all seem to gum up the watch's works, or put bugs in the program, to extend each analogy.

It is foolish, however, to simply dismiss TSS and TSB due to non-training stresses; since each is grounded in known facts of exercise physiology, they are the best available (and the *only* objective) means of quantifying training stress and assessing training load – and the need for precision in these areas is at its *greatest* during periods of increased stress. There is always an art to using any index of performance (whether obtained in the lab or the field), which should take all relevant outside factors into account, but while perceptions and markers of fatigue remain an important means of monitoring training response and guiding/adjusting the training plan, they lag overreaching/overtraining during the training year, just as perceived exertion lags power output during a workout. TSS and TSB allow training dose and training load to be precisely administered and realistically evaluated, so long- and short-term fatigue can be minimized at the very least, if not avoided entirely.

Q: *You make several claims – that CTL and ATL are substantially different from simple 42 and 7-day TSS averages, and the same thing about work and TSS – but you have presented nothing to show this.*

A: Check out this graph, which uses TSS averages, and compare it with its counterpart, Figure 5:

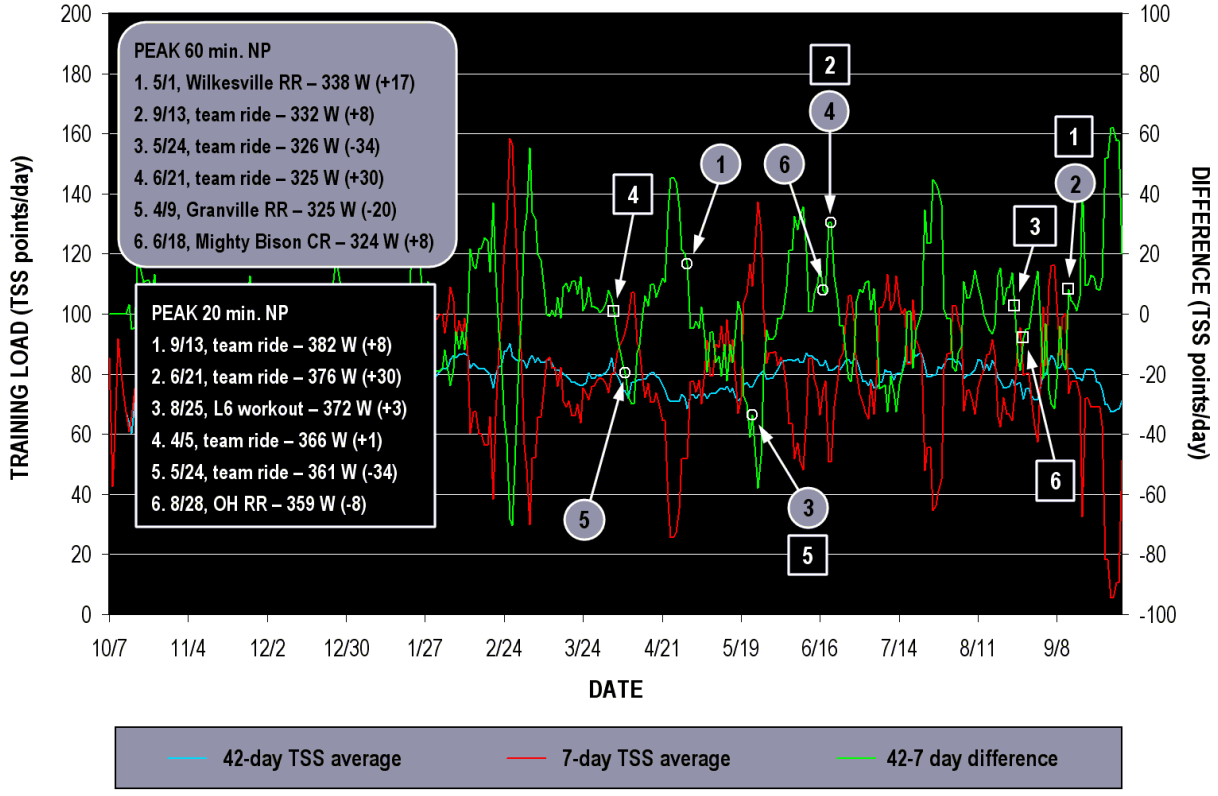


Figure 6. Rolling TSS averages for Scott Thor's 2005 season.

Note that the volatility of TSS averages shifts almost half of all peak performances significantly, usually in a negative direction:

Table 2. A comparison of stress balance calculation methods.

PERFORMANCE DATE	42-7 DAY AVG.TSS DIFFERENCE	TSB	SHIFT
4/5	+1	-1	+2
4/9	-20	-1	-19
5/1	+17	+21	-4
5/24	-34	-22	-12
6/18	+8	+16	-8
6/21	+30	+13	+17
8/25	+3	+1	+2
8/28	-8	+6	-14
9/13	+8	-2	+6

As for comparing TSS to work output, some have noted the tight correlation between the two, then concluded hastily – and mistakenly – that there was little difference:

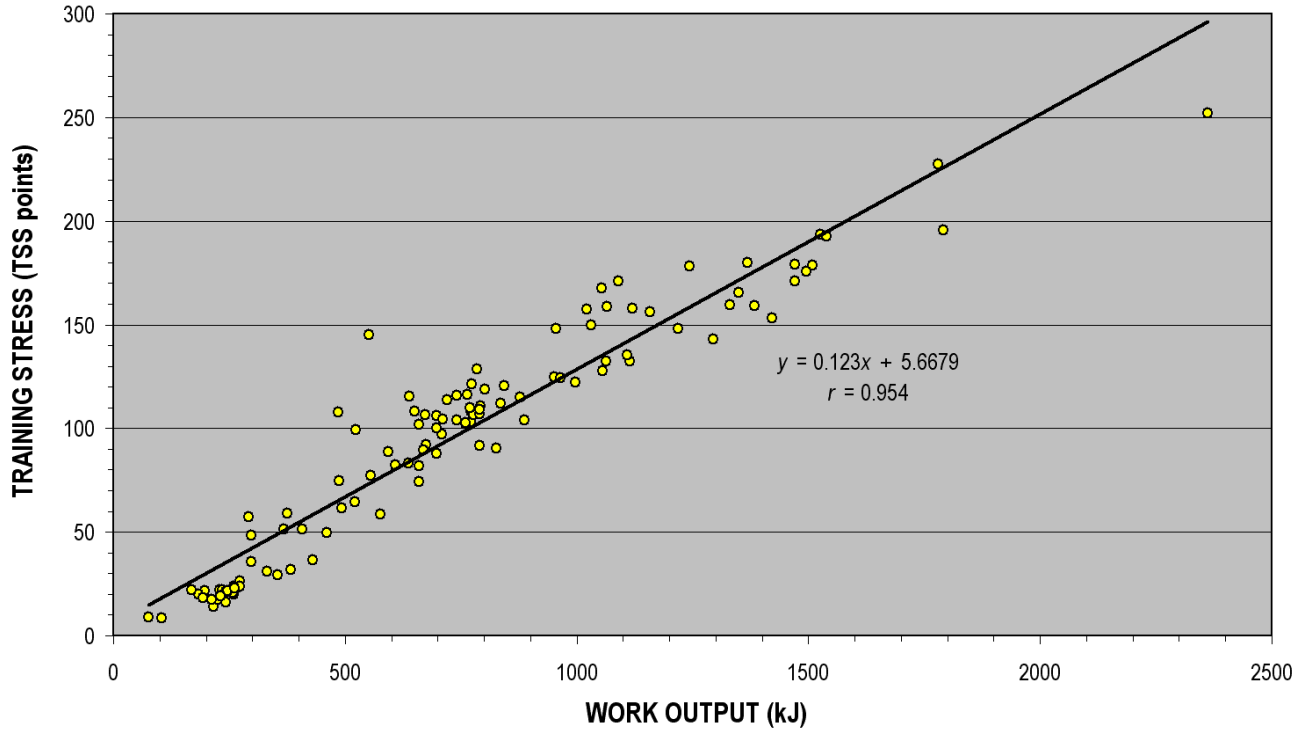


Figure 7. Training stress vs. work output for the author's 2005 season.

A more careful analysis finds that, in fact, the relationship can vary by more than threefold, depending on overall ride intensity, and, to a lesser extent, how much intensity varied during the ride. Simply (and somewhat narrowly) put, the higher the rate at which a unit of work is performed, the more stressful it is:

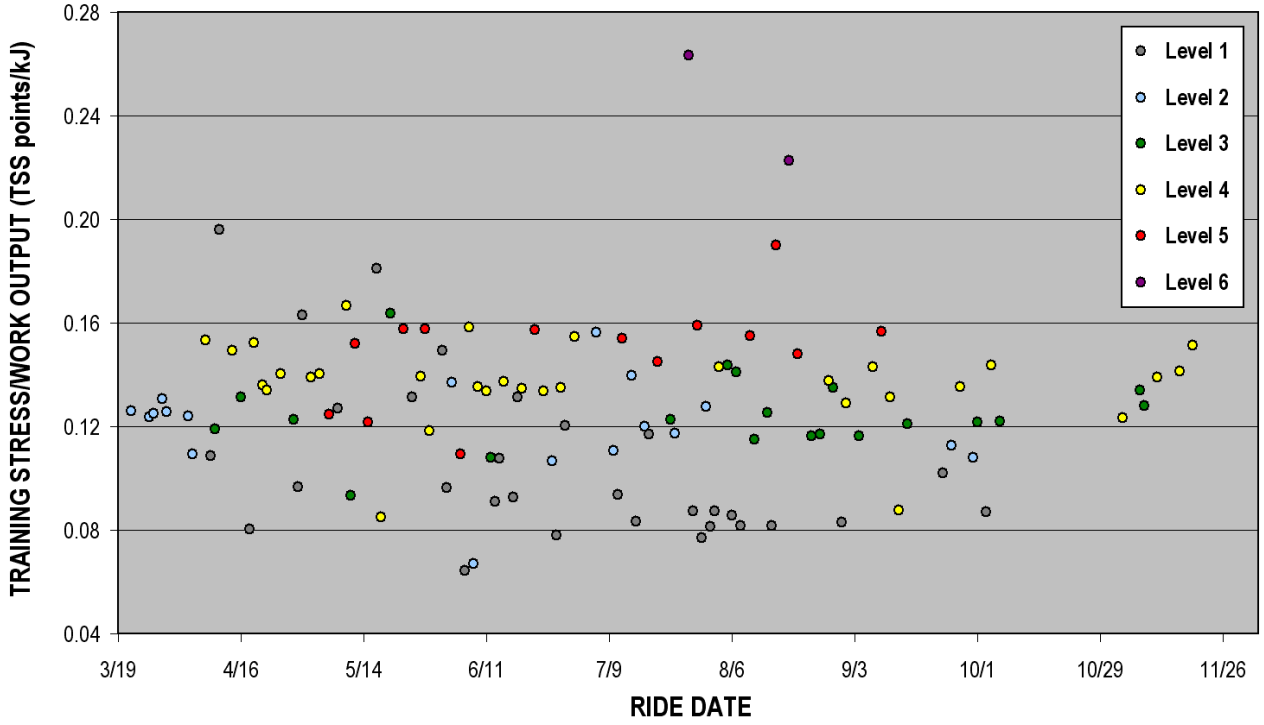


Figure 8. Training stress/work output ratio by ride type for the author's 2005 season.

*Q: Aren't the **type and relative amount** of training you do, i.e., how much time is apportioned between interval training, solo steady-state rides, high-variability group rides/training races, hilly terrain, etc. – aren't these factors just as important as the amount of stress imposed?*

A: You've hit on a fundamentally important point: TSB indicates just that, the *balance of chronic and acute training stress loads* – no less, and no more. It does not indicate training *composition*, therefore, it is quite possible to have a favorable TSB, yet not be optimally prepared, say, for a hillclimb, if you have not included enough work that is specific to the event.

Q: What are some values to aim for?

A: Professional and elite riders reach a CTL of at least 110-120 before stage races (and finish up the Tour de France around 140-150), while a Cat. 3 or masters competitor will typically need to be in a range of 70-80.

Just as important is the *rate* at which CTL is raised; increasing it by 7+ points per week (or a weekly gain in ATL of more than 70) for more than two consecutive weeks appears to invite overreaching, although this varies with individual factors such as tolerance for training, non-training stressors, age, etc. Exceptions may also occur in the early season, when CTL is low, or when training resumes after a hiatus.

With respect to TSB, a deficit of 40-60 seems to be the point at which most riders will feel the need to back off for a while, with a similar caveat about the early season. On the other hand, a highly negative TSB late in the season, when CTL is high, will likely be accompanied by greater fatigue for the given value.

In practical terms, the time-tested rule of no more than a 10% increase in training load per week works pretty well, although applying a fixed per cent increase every week causes training stress to rise exponentially. Building up in a linear fashion, simply by adding a fixed number of points each week, is more sustainable.

What these guidelines point up is the need for consistency in training, i.e., not allowing CTL to fall too much in the off-season, nor increase too rapidly when the weather improves and spring fever sets in.

Q: Is it really possible to get TSS totals to come out each week exactly as planned?

A: Maybe not *exactly*, but you should be able to come quite close (i.e., 10-15 points, or ~2%), and the more precisely you execute any training plan, the better you can judge its effectiveness. Compiling a table of typical workouts, along with the graph below, can help plan your training schedule.

Table 3. Estimated Training Stress Score totals from typical training rides.

ROUTE	WORKOUT DETAILS			TSS (pts.)
	Type	Duration (hr:min)	Intensity Factor (IF)	
Valley Parkway (flat, sheltered)	Level 5 – 5 x 5 minutes	1:35	0.87	120
Columbia Station (flat)	Level 4 – 2 x 20 minutes	1:15	0.90	100
Valley Parkway (flat, sheltered, few stops)	Level 3	2:00	0.88	155
Carlisle Twp. (flat, numerous stops)	Level 3	2:10	0.85	155
Oberlin (flat, numerous stops)	Level 3	2:30	0.83	170
Brecksville (rolling/hilly, numerous stops)	Level 3	3:00	0.80	195
Columbia Station (flat)	Level 1	1:00-1:30	0.60	35

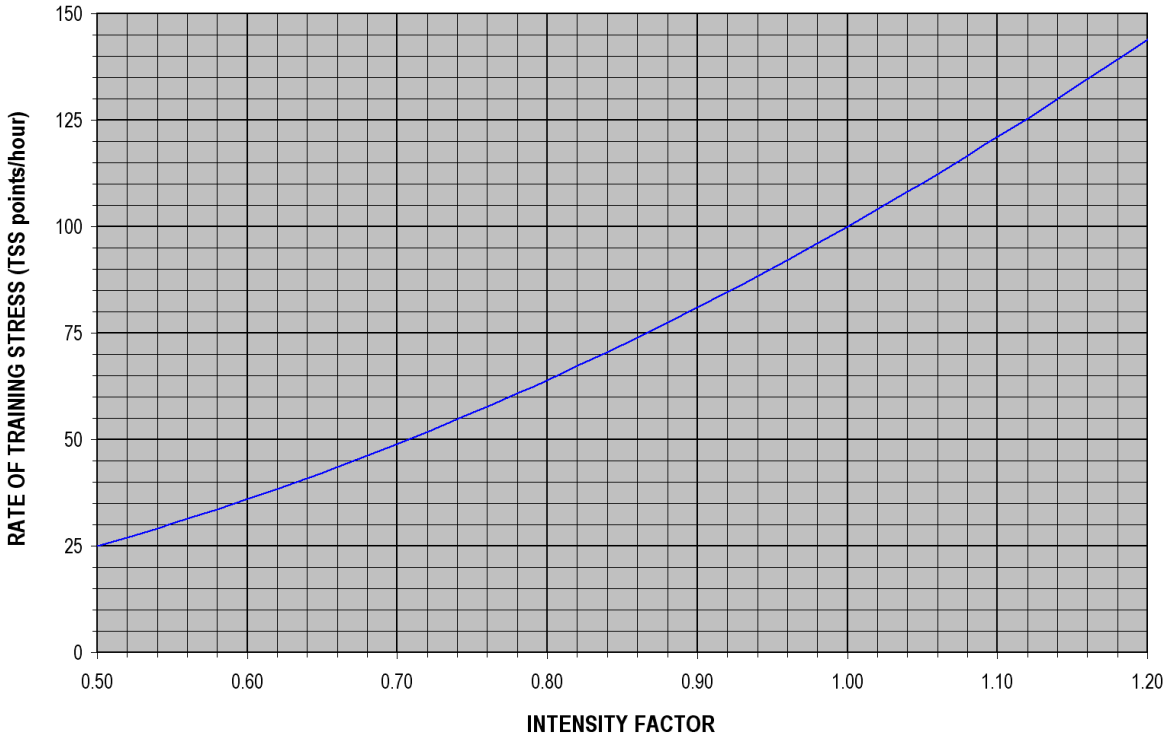


Figure 9. Training stress rate as a function of Intensity Factor.

Q: What you're actually doing, then, is to plan training by duration.

A: Ah, but TSS is what allows training stress to be quantified in a way that makes physiological 'sense,' and then used to estimate duration. Besides, what good would it do to say "Honey, I'll be back in 200 TSS points" as you're going out the door for a ride?! ☺

Q: Going beyond base training, how can the Performance Manager be used when it's time to peak?

A: Consider these two graphs, reprinted with permission from Dr. Coggan:

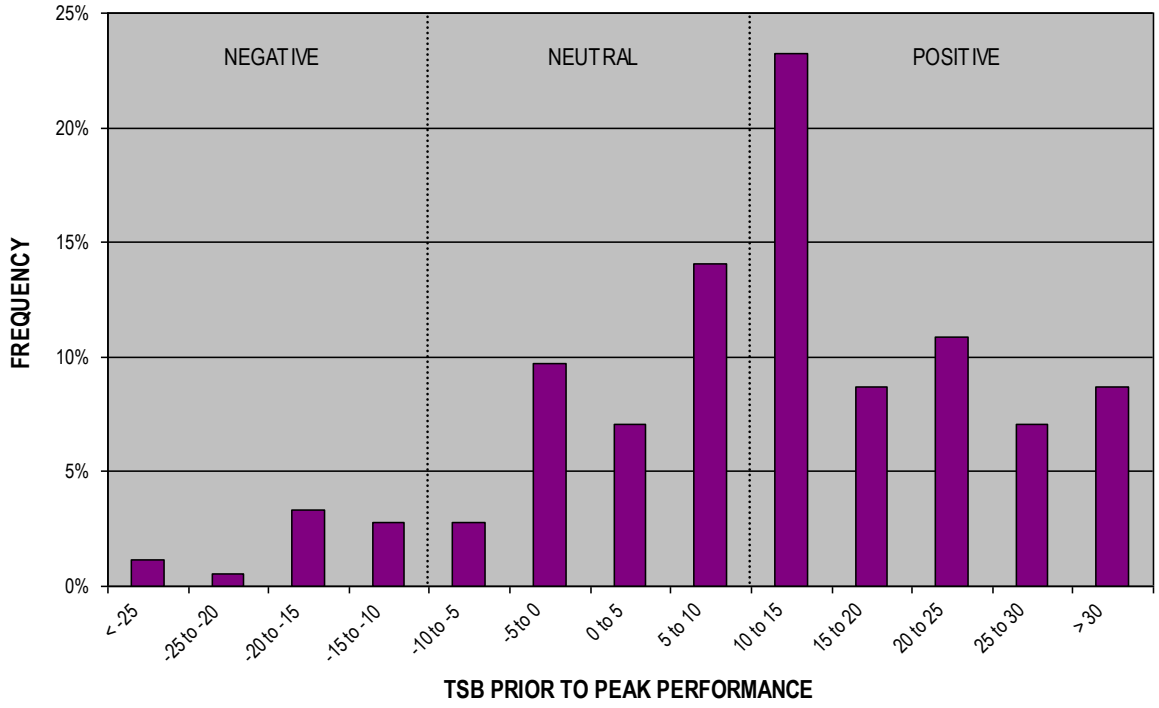


Figure 10a. Frequency of peak performances (sub-5 minute power) relative to TSB.

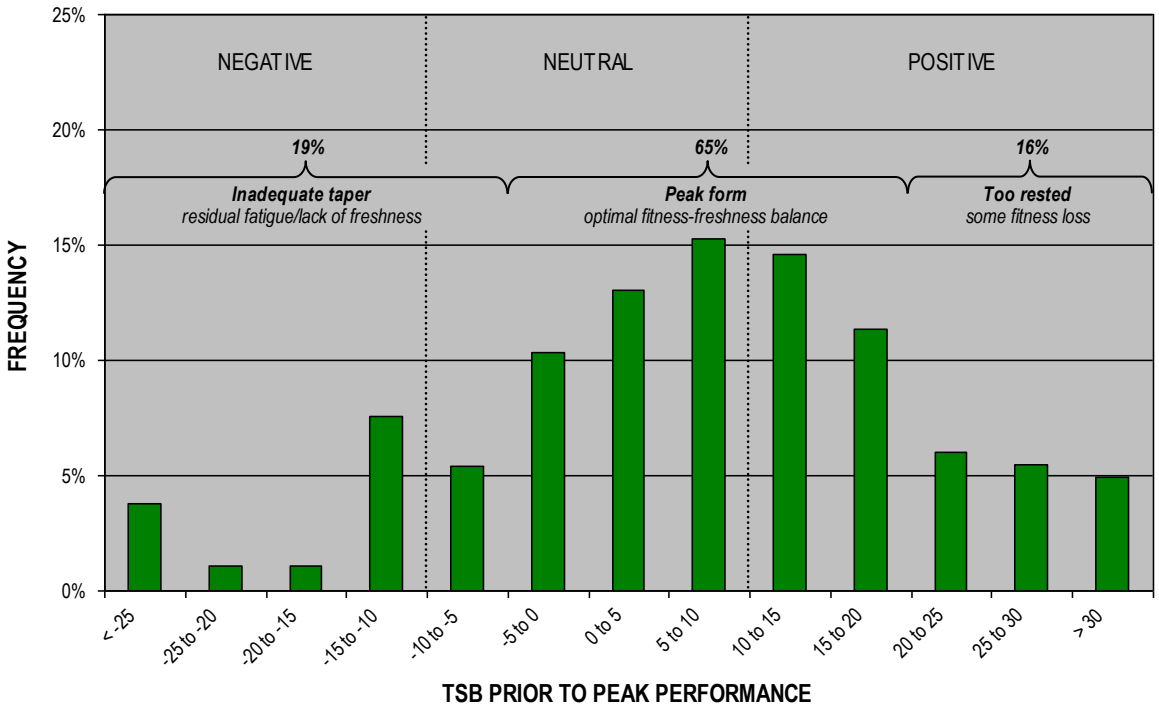


Figure 10b. Frequency of peak performances (5+ minute power) relative to TSB.

What they show is that best performances in short-duration events (Figure 10a) usually occur when TSB is within a range of +5 to +25, and 0 to +20 for events over 5 minutes (Figure 10b). Higher values of TSB indicate a more rested condition, allowing greater recovery of anaerobic power for shorter-duration events

Q: Values of TSB depend on the time constant (TC) used, right?

A: Yes, the time constant for CTL is sufficiently long that it doesn't matter much what value you use, as long as it is reasonable. On the other hand, ATL, and hence TSB, are fairly sensitive to the use of different time constants, so that is where you might want to experiment, or "fine tune" the ATL TC for various reasons:

1. for riders targeting short duration events (e.g., points races and short criteriums, short/prologue TTs, pursuit), a longer TC (10) allows more rest and greater freshness on race day
2. for riders targeting long endurance events, a shorter TC (5-7) may be used to minimize fitness loss
3. riders who need greater recovery, such as masters, might try a longer TC (~10)
4. when CTL is high (e.g., late in the season), raising the TC from the "normal" value used in-season may work better. Presumably this is due to accumulated stress over a season (and a good argument for periodically taking a week off of the bike.)
5. as previously discussed, individuals with lighter training loads (CTL <65) carry less chronic fatigue, so a very short (2-3) TC can be used – or CTL alone may suffice to indicate form

Alternatively, and much more simply, you could leave the ATL TC at the default of value of 7, then let your expectations and perceptions be tuned to the resulting TSB values.

Special thanks to Andrew Coggan for sharing his creation, and to Scott Thor for doing the same with his training data.

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