Note to Team in Training Coaches:

The following article presents an overview of measures of training stress.

As it is comprehensive, it includes simple as well as sophisticated methods.

Some of the sophisticated methods are complicated, cumbersome, or expensive. Such methods are included for completeness.

For the vast majority of Team in Training participants, and for most coaches, heart-rate and power monitors are an unnecessary expense.

Most TNT riders, beginners, are stressed by gradually increasing the distances they ride, rather than through intensity training.

Best wishes,

Arnie Baker

ABC Handout

ARNIE BAKER CYCLING

Measuring Training Stress

Implicit in the very word itself, athletic training is the process of improving fitness.

Physical training is a stress, to which the body responds. As with all stresses, some stress may be good, too much may be bad.

How much is enough, how much is too much?

CYCLE HANDOUT

Introduction

Can we qualify or quantify training stress in order to prepare and plan to obtain enough, but not too much; to improve, to provide adaptation, to peak, and yet not to overtrain?

A training log is basic to the process.

Bicycle workout variables include volume and intensity, as well as less common but potentially important factors including cadence, bicycle position, pedal stroke emphasis, and environment (altitude, climate, group setting, and terrain). These factors can help provide a qualitative or quantitative measure of training stress.

Quantitative training-stress measures generally relate to volume, intensity, or both.

As with measures of training volume and intensity themselves, all methods of evaluating training stress have pros and cons.

There is an interaction between training intensity and volume: as intensity goes up, volume must come down; and vice-versa: as volume goes up, intensity must come down.

Training stress indices have been developed that are based on both volume and intensity defined by heart rate or power.

Used singly or in combination, measures of training stress together can provide valuable insight.

Volume-Based Training Stress

Miles

Ask someone how much he or she rides.

Most US riders respond by quantifying their volume in terms of average miles ridden during a week (elsewhere, riders may quote their volume in kilometers).

Inexpensive bicycle computers make it easy to note and log miles ridden.

Other things being equal, the number of miles ridden provides one of the best and easiest methods of quantifying training stress.

A problem arises: other things are often not equal.

Hours

Riding Time

Some believe that mileage does not really count as much as time. The time-based approach is reasonable because in some ways the body responds more to riding time than to miles.

Consider: Alone, you might ride 15 miles in one hour. In a group, with drafting, you might ride 20 miles. It may be more accurate to express training stress in terms of one hour than 15 miles, or 20 miles.

Inexpensive bicycle computers may be set to start and stop at the end of rides, or to accumulate only riding time—for example, they may stop and automatically restart for traffic lights.

Chamois Time

Some feel that the moment you start riding until you finish a ride is all part of training and stress exposure, calling this time in the saddle, or chamois time.

This group feels that occasional stops during the course of a ride should not be discounted.

It is also easier, with just a watch and no bicycle computer, to note when you start a ride and when you finish, and calculate the total elapsed time.

If you arrive at your job at 9:00 AM and leave at 5:00 PM, have you worked an 8-hour day? Or have your worked 7 hours, because you took half an hour for lunch and had two 15-minute breaks?

Arguments can be made either way.

Continued

ABC Handout

In looking at training stress for any given individual, and monitoring training time—whether riding or chamois time—what matters is consistency.

Climbing Volume

For those training for hilly centuries or ACE (Altitude-Climbing-Endurance) events, performance at the event and training stress is all about climbing.

Noting and logging climbing volume, with a simple computer that tracks positive elevation changes, may provide the best method of planning, recording, and predicting performance for climbing events.

Kilojoules of Work

Accurate power-meter computers, make it possible to document accurately the total work performed during a training session, week, or month.

Relatively expensive, such devices are becoming more common and a standard training tool for athletes and coaches.

Intensity-Based Training Stress

Perceived Exertion

Just ask: Was the ride hard, moderate, or easy? It is often easy to tell.

More complicated systems of rating perceived exertion, including the Borg scale, are in common use.

Interval Work: Minutes

Some coaches and athletes monitor minutes of interval work per training session, week, month, or other period.

For example, coaches may prescribe 90 to 120 minutes of aerobic work at a heart rate over 80% of maximum per week; or a total of 5 minutes of sprint work a week.

An athlete who accumulates more than a certain number of minutes of training above a certain heart rate may be at risk for overtraining. For example, 180 minutes of aerobic work at 85% of maximum during one week may be an overtraining risk for some athletes.

Interval Repetitions, Number of Interval Sessions

The total number of intervals performed during a session, week, month, or other period may be used as a predictor of training stress.

The total number of training days with intervals per week or month may also be used as an indicator.

Many coaches believe that athletes should not engage in more than three interval training sessions per week; and that one or two such sessions may be enough, occasionally too much.

Interval Average Heart Rate, Power, or Work

The athlete's average heart rate, power, or work for intervals, for a climb, or for a race reflects how hard an athlete works.

Average heart rate may be an absolute number or a percentage of maximum.

Power may be average watts or average watts per kilogram. Interval work may be recorded in kilojoules. Like heart rate, watts values may be compared to the athlete's maximum capabilities.

Power-meter software may automatically find and report the highest average power for any segment from 5 seconds to 1 hour, or number of segments of any specified duration over any specified power level.

Number of Races/Racing Days

The total number of racing days per week, month, or season may also be used as a predictor of training stress.

Volume- and Intensity-Based Stress Indices

Volume and intensity may be combined to yield a single number or index reflecting training stress.

Heart-Rate Based Indices: TRIMP and Variants

Dr. Eric Bannister proposed the Training IMPulse (TRIMP) in 1975. Others have developed it further.

The TRIMP score of a training session is determined by multiplying the training volume by the training intensity. There are many TRIMP-type methods and formulae.

Basic-Method TRIMP

- The simplest, basic-method formula is:

TRIMP = training time (minutes) x average heart rate (bpm).

For example, 30 minutes of exercise at an average heart rate of 150 beats per minute gives a TRIMP score of 4,500.

Continued

- A more sophisticated basic-method formula is:

TRIMP = A x B x C

A is training time in minutes

B is (average training heart rate minus resting heart rate) divided by (maximal heart rate minus resting heart rate)

C is 0.64 times $e^{1.92B}$, where e is 2.712.

These relatively simple formulae may be appropriate for athletes who exercise at a constant intensity—for example average exercisers in aerobic gym classes or recreational joggers.

These algorithms do not distinguish between different levels of training. For example, 30 minutes at 150 beats per minute gives the same basic-method TRIMP score as 25 minutes at 180 beat per minute.

Zone-Method TRIMP

Heart rate zones weigh intensity in the TRIMP calculation. TRIMP zone score is calculated as the cumulative total of time spent in each training zone.

For example, here is a five-zone system:

Heart Rate, % Maximum	Zone Weight
50% to 59%	1
60% to 69%	2
70% to 79%	3
80% to 89%	4
90% to 100%	5

Table 1. TRIMP zone-method system.

If maximum heart rate is 200 beats per minute, 30 minutes at 150 beats per minute gives a zone-score TRIMP of 30 x 3 = 90. Twenty-five minutes at 180 beats per minute gives a zone-score TRIMP of 25 x 5 = 125.

This zone-method TRIMP score distinguishes between training levels and remains mathematically relatively simple. Many downloadable heart rate monitors allow the user to set up such zones and will give minutes spent in each zone.

Precision-Method TRIMP

Computer algorithms can sample every downloaded heart rate value, give a different weight to every recorded value, and sum all.

This method is similar to the zone-method TRIMP above, but instead of five training zones, there may be over 100—say every heart rate from 80 beats per minute to 180 beats per minute.

Number of Intervals

Thierry Busso's method calculates the training impulse by multiplying the number of intervals performed by their intensity based on heart rate.

His algorithm relates the positive gains from training and the negative gains from fatigue based on the real-world responses of athletes to his training impulse values.

Power-Based Indices

Normalized Power (NP)[1]

This index accounts for variability of power output during rides or ride segments longer than 30 seconds.

Normalized power is an estimate of the power that can be maintained for the same physiological "cost" if power output is constant rather than variable.

The algorithm attempts to integrate physiological response curves (principally glycogen use) to changes in exercise intensity.

Keeping track of normalized power purports to quantify more accurately the intensity of training sessions or races compared with average power.

Normalized power during a hard, one-hour criterium or road race may be similar to what a rider can average when pedaling continuously during a flat 40-kilometer time trial.

Normalized power from mass start races can provide an estimate of a rider's threshold power.

Intensity Factor (IF)

Normalized power does not take into account differences in fitness between individuals or for one person over time with changing fitness.

Intensity factor is the ratio of the normalized power, described above, to individual threshold power.

For example, if normalized power for a long training ride done early in the year is 210 watts and threshold power at the time is 280 watts, then the IF for the workout is 0.75.

However, if the same rider has the same power output later in the year, that is a normalized power of 210 watts, after fitness improves and threshold power rises to 300 watts, then the IF is lower, that is, 0.70.

Continued

[1] *Normalized Power*, *Intensity Factor*, and *Training Stress Score*, were developed by Dr. Andy Coggan. Descriptions are adapted from the CyclingPeaks website, http://www.cyclingpeakssoftware.com/, accessed August 1, 2005.

Intensity factor provides a convenient way of comparing the relative intensity of a training session or race between riders, taking into account differences in threshold power.

For example, on a training ride one rider has a normalized power of 200 and a threshold power of 250 for an intensity factor of 200 / 250 = 0.8. A second rider has a normalized power of 170 and a threshold power of 200 for an intensity factor of 0.85. The ride was relatively harder for the second rider, even though normalized power was lower.

Typical IF values, according to Coggan, for various training sessions or races are listed in Table 2.

Intensity factor can check for changes in threshold power without the need for formal testing. For example, an IF of more than 1.05 for a one-hour race is a sign that threshold power is greater than previously determined.

Intensity Factor	Typical Ride Description
< 0.75	Recovery rides
0.75 to 0.85	Endurance-paced training rides
0.85 to 0.95	Tempo rides, aerobic and anaerobic interval workouts (work and rest periods combined), longer (>2.5 h) road races
0.95 to 1.05	Threshold intervals (work period only), shorter (<2.5 h) road races, criteriums, circuit races, longer (e.g., 40 km) TTs
1.05 to 1.15	Shorter (e.g., 15 km) TTs, track points races
> 1.15	Prologue TTs, track pursuits, track miss-and-outs

Table 2. Intensity factors associated with typical rides or races.

Training Stress Score (TSS)

TSS is modeled after TRIMPS, described above. It takes into account both the intensity factor and the duration of each training session.

The following guidelines have been suggested by Coggan:

- < 150: Low (recovery complete by following day)
- 150-300: Medium (fatigue may be present the next day)
- 300-450: High (fatigue may be present after two days)
- > 450: Very high (fatigue lasting several days likely)

Power and Perceived Exertion Index

Stress-to-Strain Index

Dr. Allen Lim's stress-to-strain index is the ratio between actual work done calculated from direct measures of power and the work done calculated from perceived exertion.

"In the same way, we use a 'wind chill factor' or 'heat index' to correct for temperature, we use the 'stress-to-strain index' to correct for how hard (the rider) feels relative to … actual power."[2]

Index Value	Interpretation
<1.0	Rider feels effort was easier than what actually happened.
1.0	Perception of effort matches what actually happened.
>1.0	Rider feels effort was harder than what actually happened.

Table 3. The Stress-to-Strain Index

Confounding Variables

A host of factors can create discordance between measures of intensity (and therefore measures of training stress).

For example:

- Altitude
- Changing fitness
- Dehydration
- Glycogen depletion
- Group vs. solo riding
- Illness
- Medications and drugs
- Recovery/fatigue state from prior training
- Temperature and humidity
- Fast-twitch vs. slow-twitch muscle type
- Cross training, including eccentric training
- High-torque training
- High-cadence training

In some cases, confounding variables change the perception of effort. For example, riding in a group at 80% of maximum heart rate often feels easier than riding solo at 80% of maximum.

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[2] Dr. Allen Lim, Bicycling Magazine online, http://www.bicycling.com/tourdefrance/experts/columns/0,5976,s1-12520-527,00.html?category_id=527, accessed August 4, 2005.

In other cases, confounding variables change the physiologic demands and stresses of the effort. For example, it is not just that riding at a given power output, say 250 watts, at an elevation of 8,000 *feels* harder than at sea-level, it *is* harder in terms of absolute power, heart-rate, or speed that can be maintained.

Keep it Simple

Measures of training stress can be used to evaluate an individual training session, or multiple sessions over training cycles of weeks, months, or other periods.

Some coaches and riders may spend many hours pouring over multiple variables and analyzing stimuli and responses. For many others, this is too much analyzing. Sometimes one single measure, despite limitations, works best.

If you use a power-based index to monitor training, keep in mind that every workout must be recorded with your power meter, or you will be missing data points.

As Tour de France team leader Floyd Landis has said: "I've seen guys pouring over data, analyzing and reanalyzing for hours. For me, I just want to know how much power I sustain on climbs and in time trialing."

Arnie's Simple Method

From coaching hundreds of athletes over many years, I have found that barely one half keep regular training logs—despite the fact that a log is basic to effective coaching, documenting training, predicting performance, and preventing overtraining.

Simplicity for the rider is therefore key, although as a coach I am quite eager and willing to look at the minutia of heart-rate and power downloads, and provide detailed analysis.

At a minimum, I ask for just the basics—a single line per day on a spreadsheet, with a few figures and notes about the day's training.

After I am confident that riders know the meaning of easy riding, I like details from hard workouts including heart-rate and power files, and a grid of details for interval work.

For the basics, I use a simple Excel spreadsheet log with conditional formatting. This allows automatic color-coded highlighting of volume, intensity, perceived fatigue, mood, and a few other variables.

The color-coded conditional formatting is set to the level of the rider. For volume of training, in miles, a ride less than 20 miles might be color-coded green, a ride 20 to 50 miles color-coded yellow, and a ride more than 50 miles color-coded red.

I instruct riders to count as hard days those in which they race, perform interval work, or accumulate more than 30 minutes of work at heart rates greater than 80% of their maximums.

The colors create easy patterns to recognize. Lots of reds: beware of overtraining. Lots of greens: recovery period or perhaps not enough training stress.

A typical week's log is reproduced in Table 4.

Continued

Day	Date	Volume, Miles	Volume, Hours	Climb, K Feet	Work, Megajoules	Intensity	Intervals or Race?	PM / HRM?	SWL?	Group	Type	Location	Hours Sleep	Sleep Quality	Recovery	Resting HR	Mood in AM	Energy on Ride	Weight, Pounds
MO	Aug 1	0	0.0	0	0.00								8.0	5.0	5.0	47	5.0		
TU	2	40	3.0	0	1.0	H	I			ABC	Tandem	Fiesta Island	8.0	4.0	5.0	50	5.0	5.0	135.0
WE	3	65	6.0	5	1.8	M		PM		ABC	Road	Honey Springs	8.0	4.0	3.0	50	5.0	4.0	
TH	4	35	2.0	4	0.80	H	I	PM	Yes	ABC	Trainer	1820	8.0	4.0	4.0	48	5.0	4.0	
FR	5	5	0.5	0	0.2	E				Solo	Fixed Gear	Errands	8.0	5.0	3.0		5.0	4.0	
SA	6	50	4.0	3	1.5	H		PM		Club	Road	Gorman Loop	8.0	4.0	5.0		5.0	4.0	
SU	7	65	6.0	5	2.1	M		HRM		ABC	Tandem	DeHesa Japatul	8.0	4.0	3.0	50	5.0	5.0	

Table 4. Example of a basic training log, with color-coded conditional formatting. Columns record training volume in miles, hours, feet climbed, and kilojoules of work; training intensity in terms of perceived exertion, interval work, and racing; type of ride; and location. PM/HRM/SWL cross-references power meter, heart-rate-monitor, or specific workout logs for interval training. ABC is Arnie Baker Cycling coached group of riders. Columns for other markers of training and non-training stress, rated on a scale from 1 to 5, include: sleep quality, perception of recovery, mood, and ride energy. Other columns, not shown, calculate and chart weekly, monthly, and annual totals.

With experience, color pattern recognition makes it easy to notice too much or too little training, and to be on the alert for overtraining. The Wednesday ride on the 3rd was, for this athlete, a long ride performed at a moderate intensity. Overall, the week was a good week of mid race-season training, with two long rides, three hard days, one easy day, and one day completely off.

A Practical Example—Arnie's Wednesday Ride

For 20 years I have ridden a midweek endurance ride almost every Wednesday.

In its current version, we ride 65 miles. The first and last hours are always at an easy pace as we ride through city streets to the outskirts of San Diego.

After some rollers, we climb 6.5-miles up Honey Springs Road, with almost 2,000 feet of vertical. Then a rest stop for refueling, a 5-mile race simulation culminating in a sprint, and up to 10 sprints points on the way home, mostly up rollers. Riders choose to participate or not in the race simulation and sprints.

For some us, the whole day is of low intensity; sometimes we work hard going up the climb or on the sprints, or on both.

How do our stress measures portray the ride?

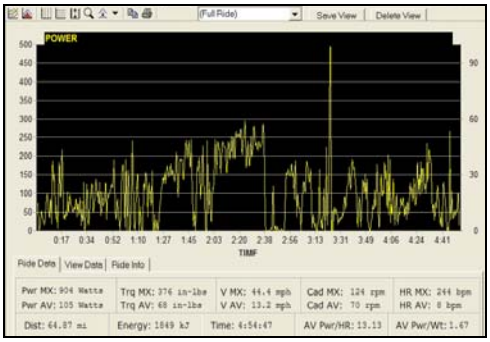

Figure 1. Typical Arnie's Wednesday ride. About 65 miles, 5 hours riding time. Steady climb at about 225 watts. One sprint to 904 watts.

Volume

- *Distance*: The ride is always the same, 65 miles.
- *Time*: Chamois time is always about 6 hours, ride time about 5 hours. If we climb harder, we seem to need more recovery later and ride slower in the second half of the ride. If someone gets a flat tire, the rest period seems to energize us and we make up the lost time.
- *Climbing*: The ride is always the same, totaling about 5,000 feet.
- *Work*: The ride is always about the same, about 1,850 kilojoules for a typical 135-pound rider. Hard efforts are made up climbs and rollers; aerodynamics do not matter much. Whether one climbs Honey Springs in 30 minutes or one hour, the work against gravity is the same.

Intensity

- *Perceived exertion*: Can range from easy to hard, depending upon whether climbing hard, sprinting hard, or both.
- *Interval work minutes*:

  Intensity over 80% max heart rate: Riding easy, there may be only a few minutes; riding hard, up to 60 minutes.

  Sprint work: Zero to 5 minutes total.
- *Number of intervals*:

  Aerobic: Up to four 5- to 40-minute intervals.

  Anaerobic: Up to 10 sprints.
- *Interval average heart-rate power*: Our typical rider climbs Honey Springs at 135 beats per minute or 70% of maximum heart rate easy. He climbs at 165 beats per minute or 87% of maximum heart rate hard. Power ranges from 130 watts easy to 265 watts hard; or between 2.2 and 4.5 watts per kilogram.

Indices

To review the definitions of training stress indices, see the discussion beginning on page 3.

- *TRIMPS*: Our typical rider averages 300 minutes at 120 to 150 beats per minute for a 36,000 to 45,000 TRIMP score.
- *Normalized power*: Our typical rider accumulates 1,850 kilojoules of work over 5 hours riding time and averages 370 kilojoules per hour, or about 105 watts per hour.

  Normalized power, accounting for variable power output, here mostly on climbs, ranges from a low of about 150 watts to a high of about 200 watts.
- *Intensity factor* is generally about 0.7. Riding easy results in a value of about 0.6. Climbing hard and performing all-sprints results in a value of about 0.8.

  According to the index's author, this generally represents a recovery ride.

  Note: If a rider performed the 0.8 ride, without our long warm-up and cool-down, the intensity factor would go up to 1.1, typical of a track points race or 15-kilometer time trial. The intensity factor would be higher for the shorter ride even though the longer ride would be everything the shorter ride was and more.

Continued

- *Training stress score* typically ranges from a low of about 200 to a high of about 300. According to the index author, fatigue may be present for one or two days after such TSS values.
- *Stress to strain:* Typically, the ride feels about as hard as the rider makes it. Confounding variables, such as heat during the summer, or riding following a hard Tuesday evening interval session, make it feel harder than it is.

Simple Method

It is a long-easy to long-hard ride.

Summary

Noting and recording one or more measures of training stress in a training log can help athletes and coaches monitor the adequacy or excellence of training or racing or both, and serve as markers for peaking or overtraining.

The bottom line for any individual: What works, what is easy to use, and what will be consistently used.

AB

Stress Measure	Pros	Cons
Volume		
Distance	Simple, best with odometer Good if effort relatively constant	Misses intensity of segment
Time	Simple Good if effort relatively constant	Misses intensity of segments If distance is fixed, shorter times reflect harder, not easier workouts
Climbing	Simple, best with climbing computer	Misses intensity of segments
Kilojoules	Accurately reflects total work	Misses intensity of segments Requires power meter
Intensity		
Perceived exertion	Free Simple	Subject to confounding variables
Interval work minutes, numbers	Relatively simple for numbers and minutes	Requires power meter to quantify watts during intervals
Indices		
TRIMPS	Recognizes intensity of segments	Requires heart-rate monitor
NP	Recognizes intensity of segments	Requires power meter and software
IF	Recognizes intensity of segments Relates to individual	Requires power meter and software
TSS	Recognizes intensity of segments and overall volume of ride Relates to individual	Requires power meter and software
Stress-to-strain	Accounts for confounding variables	Complicated Requires power meter Requires prior testing
Simple		
Simple	Simple Conditional formatting makes pattern recognition easy	Less quantitative than some other methods Pattern recognition requires some science, some art, and some experience.

Table 5. Pros and cons of different methods of evaluating training or racing stress. All measures are subject to confounding variables, as discussed on page 5.

For More Information

The following publications are available through arniebakercycling.com:

Books

HIT—High-Intensity Training for Cyclists
Smart Cycling

Slide Shows

Intensity Training
Interval Training
Stationary Training

Handouts

Cycling Fitness Elements
High-Intensity Training Tips
Isolated Leg Training
Max Aerobic Power Testing
Training & Fitness Standards for Excellence