Training load quantification in triathlon

ROBERTO CEJUELA ANTA[1] , JONATHAN ESTEVE-LANAO[2,3]

[1]*Department of Physical Education and Sports, University of Alicante (Spain)*
[2]*Training Lab, European University, Madrid (Spain)*
[3]*School of Exercise Sciences, Greenwich University, London (UK)*

ABSTRACT

Cejuela-Anta R, Esteve-Lanao J. Training load quantification in triathlon. *J. Hum. Sport Exerc.* Vol. 6, No. 2, pp. 218-232, 2011. There are different Indices of Training Stress of varying complexity, to quantification Training load. Examples include the training impulse (TRIMP), the session (RPE), Lucia's TRIMP or Summated Zone Score. But the triathlon, a sport to be combined where there are interactions between different segments, is a complication when it comes to quantify the training. The aim of this paper is to review current methods of quantification, and to propose a scale to quantify the training load in triathlon simple application. **Key words:** PERFORMANCE, HEART RATE, TRIMP, TRAINING ZONES, RPE

Corresponding author. Facultad de Educación, Campus de San Vicente del Raspeig. 03540. San Vicente del Raspeig (Alicante). Spain.
E-mail: roberto.cejuela@ua.es
Submitted for publication February 2011
Accepted for publication March 2011
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.4100/jhse.2011.62.03

INTRODUCTION

Endurance sports have evolved considerably in recent years, both in practice and in the diversity of disciplines, as well as in absolute and relative performance levels. This all makes it necessary to research into new methodologies for competition analysis along with more advanced training and performance control techniques, based on sciences such as physiology or biomechanics. Apart from being specialists in sports techniques, today's trainers must be aware of these breakthroughs, use these sciences and become part of the knowledge widening process in a field where everything seemed to be known already. It is true that this quality –and particularly in sports such as cycling or endurance races– has always been studied with special attention from the very beginning of physiology and biomechanics of effort (Banister & Calvert, 1980). However, the same as in all sciences, the initial knowledge has been gradually replaced with new breakthroughs and, particularly, new concepts have emerged which qualify or break away from the classical beliefs. Thus, thanks to the new, more accessible and practical technology, sports are being analyzed from a more complex perspective, both in internal load (Faria et al., 2005; Bernard et al., 2009) and in external load (Cejuela et al., 2007; Vleck et al., 2007). The complex metabolic, neuromuscular and mechanic interactions of exertions in these competition models are being studied, and new periodization and control methods and models are proposed to face up both to these breakthroughs and to dense and extended competition calendars (Wood et al., 2005; Hayes & Quinn, 2009). Both competition analysis and training quantification are basic elements in the training process on paper and, however, we still have to deepen our knowledge of these two areas to a great extent if we want to understand and control the process better.

Sports training quantification has always been a goal for researchers on sport sciences. There are numerous publications (Iliuta & Dimitrescu, 1978; Bannister, 1980; Morton et al., 1990; Mujika et al., 1996; Lucía et al., 1999; Borresen & Lambert, 2009; Hayes & Quinn, 2009) which have as their aim to validate or propose different methods to measure and control training load. Furthermore, the evolution of knowledge also forces an evolution in control and quantification protocols. However, most sports trainers quantify training subjectively (due to a lack of means or knowledge), which entails a severe risk for the health of sportsmen and women who follow a training plan in which neither the effects of exercise nor their individual adaptation level are monitored.

Within endurance sports, triathlon is a sport where three exercises (swimming, cycling and running) are developed in a continuous way, these three being the most common exercises among human forms of locomotion. As a result of the interactions in the performance of these three exercises, triathlon is a complex sport in terms of training load control and quantification. This complexity makes triathlon very interesting when it comes to propose a method which can quantify the value of each training session and its interaction with the other sessions, a method which can also be valid to monitor other exercises with similar characteristics.

INDICES OF TRAINING STRESS

Quantification by perceived exertion (RPE)

The use of perceived exertion scales (in 6-to-20 or 0-to-10 versions) to indicate exertion intensity in endurance or strength is widely acknowledged. Likewise, the 0-to-10 scales to quantify both types of effort have been validated in studies about training quantification where their usefulness was checked in relation to objective physiological variables (Sweet et al., 2004; Seiler & Kjerland, 2006; Foster et al., 2001). In this respect, the method developed by Foster et al. (2001) suggests assigning a perception score on the global value for the training session, which is multiplied by its length. This is done more or less within the 30 minutes following the session, preventing the sportsman or woman from being guided by the recent RPE after a specific exertion, and making it more representative of the total load. Figures 1 and 2 show the scale used along with an example of the calculation.

Scores	Descriptor
0	Rest
1	Very, Very Easy
2	Easy
3	Moderate
4	Somewhat Hard
5	Hard
6	-
7	Very Hard
8	-
9	-
10	Maximum

Figure 1. *Scale [Rate] of Perceived Exertion (RPE) used by Foster et al. (2001), which is passed about 30 minutes after the end of the session with this question: "How was your workout?".*

Training Session	Session RPE (0-10)	Session Time (min)	Total Load Index
Monday: 40' Extensive Training	2	40	80
Tuesday: 20' Extensive Training + 6x4' Anaerobic Threshold r'=1' + 20' Extensive Training	7	70	490
Wednesday: 30' Extensive Training + Maximum Strength	6	70	420
Thursday: rest	0	0	0
Friday: 30' Extensive Training + 2x30' Moderate Training	6	90	540
Saturday: 30' Extensive Training + Explosive Strength	5	70	350
Sunday: 180' Extensive Training	4	180	720
		TOTAL:	2600

Figure2. *Example of a training load calculation following the methodology of Foster et al. (2001) with the session RPE.*

Note that it also permits to quantify strength training, although the calculation is carried out through the ‘time’ variable in addition to RPE scores.

The method has the advantage of its simplicity, as it is not indispensable to use a pulsometer or maximum endurance tests; it is not necessary to take into account the weight of pauses in the case of interval training… only the familiarization with RPE. It is additionally validated for very high intensity efforts (above MAV, Maximum Aerobic Velocity, or strength training). This unique advantage of offering the possibility to add up the load corresponding to various qualities (such as strength and endurance) which had not been proposed by any other methodology so far, presents a clear weakness, namely time quantification not only of strength training but also in general, as it considers the total session time, including pauses, and multiplies by the RPE factor.

An alternative to quantify only endurance would be to give a score to the real time at each RPE zone using the points on a 0-10 scale or the points at zones with certain percentages, like the system developed by Edwards (1993) (Figure 3). However, since the ‘score’ concept would then mean ‘session zone’ and not ‘session load’, the fault in the system lies in the fact that it obviates the density factor. It can indeed be calculated and multiplied too, as in the example shown in Table 2, but the use of these systems should be restricted to endurance-only training, and their validation with more objective variables has not been studied yet (lactate or HR). This is not possible anyway, as soon as we think of density, since it would be arbitrary, and Foster’s system gains ground because it refers to a ‘session impact’ index, not to RPE only as ‘intensity.’

Example: 20’ in RPE 3 + 20’ in RPE 5
Total Load= (20x3) + (20x5) = **130**

Another alternative (Edwards, 1993): Add time at each one of the following 5 zones:

1 - 50-60%
2 - 60-70%
3 - 70-80%
4 - 80-90%
5 - 90-100%

(Limitations: it does not permit quantification above MAV, unless the scale is validated and changed with respect to higher intensities; neither does it weight pause time).

***Figure 3**. Scores by subjective perceived exertion zones (RPE, 0-10 scale), where the first physiological threshold in aerobic endurance would be a ‘3-4’ score, the 2nd threshold a ‘7’ score, and MAV,‘10’). The minutes at each zone are multiplied by the score and everything is added up.*

Training impulse (TRIMP) and Excess Post-Exercise Oxygen Consumption (EPOC)
"TRIMPS" is the English abbreviation for 'Training Impulses'. This method was originally proposed by Bannister (1980) and is based on the increase in heart rate (HR), gradually weighted. It is calculated as the length (in minutes) multiplied by an intensity factor which is differently defined for men and women (Figure 4).

TRIMP = duration of training (min) x (factor A x ΔHR x exp (factor B x ΔHR))
ΔHR ratio = (average HR – resting HR) / (maximum HR – resting HR)
Factor A = 0.86 and Factor B= 1.67 for women
Factor A= 0.64 and Factor B= 1.92 for men

Morton's modification (1990):
TRIMP = duration of training (min) x ΔHR x 2.718 exp (factorB x ΔHR)

Figure 4. *Original TRIMPS system (Bannister, 1980).*

$$
\begin{aligned}
W &= I(D_{\text{act}}) \times C(D_{\text{act}}) \times D \\
&= \left(\frac{v_{\text{act}}}{v_{\text{opt}}} + \frac{v_{\text{act}} - v_{\text{crit}}}{v_{\max} - v_{\text{crit}}}\right) \times \left(1 + \frac{I(nD_{\text{act}}) - I(D_{\text{act}})}{I(D_{\text{act}})} e^{-\sigma_1 \frac{\tau_{\text{rec}}}{\tau_{\text{effort}}}}\right) \\
&\quad \times nD_{\text{act}} \left(q_D + (q_{nD} - q_D) e^{-\frac{\tau_{\text{rec}}}{\tau_{\text{effort}}}}\right) \qquad (21)
\end{aligned}
$$

Where: I = Session intensity, C = Session density; and D = Session volume.

(Limitations: it does not permit quantification above maximum HR, limitations typical of HR-based control, all training sessions must be monitored; and the original system does not weight pause time).

Figure 5. *TRIMPS system Score (W) (Hayes & Quinn, 2009).*

This is a widely recognized method, although it involves relatively complex calculations and, above all, it is totally dependent on heart rate (with the implications derived from this). The same group suggested a modification to make it more representative at high intensity by adding number 'e' in its calculation (Morton et al., 1990) (Figure 4). Another modification has recently been proposed which makes it possible to overcome limitations such as the comparison between continuous and interval training and consider pauses as well as the type of recovery (Hayes & Quinn, 2009). The trouble is that calculation complexity soars and its real application on the field still has to be tested (Figure 5).

There have also been attempts to simplify Bannister's original TRIMPS method. For example, Lucía et al. (1999) reduced it to 3 phases for research purposes (Phase I below the first threshold VT1; Phase II zone between thresholds; and Phase III above the second threshold VT2). In this way, 1 point is granted per real minute at Zone I; 2 points per minute at zone II; and 3 at zone III, adding up the total TRIMPS and comparing, for instance, the stress associated with the *Vuelta a España* vs. the *Tour de France*, different types of stages or different types of endurance sportsmen and women (Figure 6).

The problem with these methods is that they depend on heart rate measurements with all the implications this has in terms of possible alterations (drift, temperature, hydration or even position on the bicycle) (Achten & Jeukendrup, 2003; Leweke et al., 1995) and specially non-quantification of work above maximum HR.

Zone I (<Aerobic threshold)	x 1
Zone II (between thresholds)	x 2
Zone III (>Anaerobic threshold)	x 3

Example: 20' zone I + 20' zone II + 10' zone III = (20x1) + (20x2) + (10x3) = **90 Lucia's TRIMP**

Example of equivalences: 60 minutes at the Aerobic Threshold zone (I) are the same as 30 minutes at the zone between thresholds (II) (30x2=60) and 20 minutes at the Anaerobic Threshold zone or above (III) (20x3=60)

(Limitations: it does not weight pause time; it does not permit quantification above maximum HR; limitations typical of HR-based control and very wide zones which do not discriminate training at a somewhat more intense level, for instance, training at Anaerobic Threshold have the same value as training at MAV).

Figure 6*. Simplified TRIMPS system (Lucía et al., 1999).*

Another method based on heart rate, but with a vision that goes beyond the mere aerobic quantification, is the one developed using the *Firstbeat* technology and proposed by Rusko et al. (2003). It requires special pulsometers, the data of which cannot be seen at once but have to be stored, downloaded and later treated using specific software.

This method has a theoretical advantage: it relies on a physiological response mechanism of the human body itself (EPOC: oxygen consumption remains high above the resting level in the post-exercise period) to quantify training stress. Nevertheless, despite being attractive, the model involves a complex calculation and a heart rate monitor, as well as special software (*Suunto*), is required. More scientific studies are needed that can provide information about this method.

Heart rate variability (R-R breadth) has also been studied for some time, but training quantification patterns are still unclear despite the promising foundations. Once again, data treatment appears as a limiting factor. However, both approaches will probably become better markers for internal training load (that is, the physiological impact caused by a program) than the conventional use of heart rate 'alone'.

Training zones

Several authors have proposed scales with coefficients which are based on the response of variables registered in the training, such as HR, paces or lactate. An adjustment is applied at each zone in order to favor a representative weight of high-intensity sessions. A non-linear trend is assumed which can additionally make it possible to count the zones above MAV. Its scientific application is justified for that reason and because it depends on the individual response, although there is always a degree of subjectivity in the establishment of coefficients that reduces its validity as an optimum tool. These systems also lack the calculation of density.

The first proposal to multiply time at a beat zone was the so-called Index of Overall Demand or Intensity developed by the Romanians Iliuta & Dimitrescu (1978). They suggested multiplying exertion length by the HR mean expressed in percentages of maximum or Reserve HR, and dividing it by total training time (Figure 7).

IOD = multiplying exertion length by the HR mean expressed in percentages of maximum or reserve HR, and dividing it by total training time.

Example: 20 minutes at 60% of maximum HR + 10x2 minutes at 85% of maximum HR

$$\mathrm{IOD} = \frac{20\times60+(10\times2)\times85}{20+20} = \frac{1200+1700}{40} = 72.5$$

Figure 7. *Index of Overall Demand (Iliuta & Dimitrescu, 1978).*

Edwards (2003) made another proposal where he modified the training impulse making it easier to quantify interval training. Training time is calculated at each one of the 5 heart rate zones obtained according to maximum heart rate (Figure 8).

Summation = (duration in zone 1 × 1) + (duration in zone 2 × 2) + (duration in zone 3 × 3) + (duration in zone 4 × 4) + (duration in zone 5 × 5)

Where zone 1 = 50% to 60% of maximum heart rate, zone 2 = 60% to 70% HRmax, zone 3 = 70% to 80% HRmax, zone 4 = 80% to 90% HRmax, and zone 5 = 90% to 100% HRmax

(Limitations: it does not weight pause time; it does not permit quantification training above 100% of HRmax; limitations typical of HR-based quantification).

Figure 8. *Summated-heart-rate-zones (Edwards, 2003).*

Once again, the preceding systems are exclusively based on the use of heart rate, with the limitations and advantages that this entails. In triathlon, the exclusive utilization of heart rate is sometimes limited by (1) the difficulty to use it in swimming; and (2) because there are other systems which are also indicative of exercise intensity, such as power in cycling or pace in running.

Mujika et al. (1996) introduced the concept of training units (Table 1) based on the quantification of training zones by blood lactate. The units were proposed to quantify training load in swimmers.

Table 1. *Training units (W) (Mujika et al., 1996).*

W = Vol (Km) x 1 + Vol (Km) x 2 + Vol (km) x 3 + Vol (km) x 5 + Vol (km) x 8

Training Intensity Levels	Coefficients
I	1
II	2
III	3
IV	5
V	8

*Abbreviations for zones. Intesities I, II and III represented swimming speeds inferior (≈ 2 mmol*l⁻¹), equal (≈ 4 mmol*l⁻¹) and slightly above (≈ 6 mmol*l⁻¹) the onset of blood lactate accumulation, respectively. High intensity swimming that elicits blood lactate levels of ≈ 10 mmol*l⁻¹ was defined as intentity IV and maximal intensity sprint swimming as intensity V.*

To calculate the training load, multiply the volume (in kilometers) of each intensity zone by its coefficient, and add to the final.

This proposal is straightforward, though still not validated to quantify training load in swimming; for triathlon it would additionally be necessary to differentiate the physiological zones for cycling and running, as well as the various energy demands corresponding to each exercise.

A PROPOSAL FOR TRAINING LOAD QUANTIFICATION IN TRIATHLON

Since all quantification methods are imperfect in nature (and so is this model), we make a relatively simple quantification proposal for triathlon.

Model goals
The main goals in this model are to integrate the complexity of these three-sport activity and the transitions between the sports; to consider volume, intensity and density; and to assess global residual fatigue (including strength training effects). The model can be also applied to each sport in isolation.

Model constants / assumptions
This model is based on the currently available scientific knowledge, but cannot be adjusted to full individualization. So, we assume that:

- Objective load should be taken into consideration in order to compare different performances objectively.
- Subjective daily total load should also be weighted for these three purposes: 1) to compare different degrees of training assimilation; 2) to observe its evolution in relation to objective load for overtraining prevention; and 3) to assess strength training impact, both in central and muscle soreness effects.

Model justification and development
The criteria considered in the model are shown below.

Objective load quantification criteria

- Training zones should be narrow enough to allow us to weight transition across them.
- Total training should be considered between events according to:

  2.1 Energy Cost
  2.2 Possibility to Maintain a Stable Technique style
  2.3 Muscle Soreness (actual and accumulated effect)
  2.4 Typical training Density

- Training load in a transition workout should be weighted with a higher value (in the second event) than when it is performed without any previous activity.

General load quantification development

A three phase model is avoided by adding “in-threshold” zones and glycolytic zones. Since pure (ATP+PCr) efforts are restricted to strength and power workouts, we do not consider more intense zones. It would not be suitable to weight these zones on an ‘invested time’ basis (as Foster et al. did in 2001). This will consequently be taken into account in the Subjective Load part of the model.

Intensity is considered exponentially –not linearly– from a general point of view (from below Aerobic Threshold to glycolytic zones) with the aim of leveling off total training stress for a given performance level. The training zone scoring system is based on the preliminary proposal by Esteve-Lanao (2007). This proposal is based on athletes’ workout perception and tries to find a factor that can level off the hardest load at every zone during a season.

It would be ideal to multiply Volume x Intensity x Density, but continuous training would show the difficulty in choosing a given rate for density. We suggest investigating individual-zone-associated time limit relationships according to efficiency, critical velocity or endurance index (Péronnet et al., 2001). Thus, zone rates could be found through a standard protocol and then scaled with respect to an arbitrary unit, where density is also considered.

Volume is quantified by time as this allows a better comparison between different performance levels and terrain conditions (pavement, uneven laps). So, to make it simple, the model multiplies volume by time and intensity using particular rates at every zone.

Thus, density is not explicitly recognized. Since most training workouts are continuous in nature, choosing an arbitrary value would be wrong from the start. However, density counts in global indexes were applied to each sport –as will be discussed below– in relation to their respective natural training.

***Table 2**. Zones and Zone Scores leading to rough Objective Load Equivalents (Sp. 'ECOs').*

Zone	SWIM	BIKE	RUN	VALUE
<AeT	A0	Ext.Training	Ext.Training	1
AeT	A1	AeT	AeT	2
AeT-AnT	A2	Moderate	Moderate	3
AnT	AnT	AnT	AnT	4
>AnT	>AnT	>AnT	>AnT	6
MAP	A3	MAP	MAV	9
LAC Cap	Lac Cap	Lac Cap	Lac Cap	15
LAC Pow	Lac Pow	Lac Pow	Lac Pow	50

<AeT. Below Aerobic Threshold; AeT: Aerobic Threshold; AeT-AnT: between thresholds; AnT: Anaerobic Threshold; >AnT: between AnT and MAP; MAP: Maximal Aerobic Power; LAC Cap: Lactic Capacity; LAC Pow: Lactic Power or Glycolytic Power.

Event relative value

The output values obtained from multiplying time by scoring value are defined as '**Objective Load Equivalents**' (or '**ECOs**', for its initials in Spanish). All values are expressed in relation to Running being '1' so that rough ECOs can be considered according to each event (swim/bike/run).

Swim load is multiplied by 0.75 and Bike load by 0.5. The justification for this is provided by an analogic comparison 4-point scale based on the current knowledge of the following topics.

***Table 3.** Event rates and transition effect to quantify ECOs*

	S	B	R
DIFFICULTY TO MAINTAIN TECHNIQUE	****	*	**
DELAYED MUSCLE SORENESS	*	*	****
TYPICAL WORKOUT DENSITY [a]	*	**	***
ENERGY COST [b]	***	**	***
TOTAL (1-4)	**9**	**6**	**12**
(%)	**75**	**50**	**100**
RATE / RELATIVE SCORE	**0.75**	**0.5**	**1**
TRANSITION EFFECT [c] (to be applied only to the second event)		**+0.10**	**+0.15**

a: Besides repetition workouts, specially common for swimming, "typical workout density" is related to global workouts, so in swimming use to be short frequent rests. These are less of them in cycling (by drafting effect and uneven routes), and almost none in running. b: The energy cost for non-drafting workouts without previous fatigue, based in equations and data from research, and applied to competitive velocities in a similar performance level through all events (Miyashita et al., 1974; Fix et al., 1977; Lamb et al., 1984; Whitt et al., 1982; MacArdle et al., 1987; Ainsworth et al., 2000; Pendergast et al., 2003; Chatard & Wilson, 2003; Zamparo et al., 2009). Interactions and fatigue are not considered here, since these values are designed for isolated sessions with no drafting. c: The transition effect value added to 2nd event. The value has been chosen based on research in the increased energy cost, increased perceived exertion and kinematic running changes after cycling, the most common transition (Vercruyssen et al., 2002; Millet et al., 2000; Millet and Vleck, 2000; Hue et al., 1998). These values could be adapted to several performance levels (Millet et al., 2000).

	OLYMPIC DISTANCE			IRONMAN DISTANCE		
	S	B	R	S	B	R
ENERGY COST (kcal/min/kg)	0.30-0.34	0.15-0.29	0.36	0.23-0.18	0.15	0.19
RELATIVE VALUES	**0.88**	**0.6**	**1**	**1**	**0.65**	**1**

The Olympic distance triathlon cycling event is assumed to have drafting (most part of the race). The energy cost range derives from that, both for swimming and cycling. The energy cost is extremely dependent on speed, as well as the triathlete's efficiency. As speed reduces, energy cost reduces dramatically. Calculations are done based on medium level performance (less than 2h and less than 10,5h).

The delayed muscle soreness value (1-4) could be higher for cycling, and thus a 0.58 rate (2 in 4 delayed muscle soreness rate for cycling, so a total 7 in 12 score leading to that 0.58). But it is also true that energy cost has been counted without drafting, while common training practice includes drafting. The drafting effect can reduce energy cost up to 40% in cycling (Lucía et al., 2000; McCole et al., 1990) and up to 11-21% in swimming (Chatard & Wilson, 2003, Basset et al., 1991). For those who always train alone, bike value would rise up to 0.58-0.60. Considerations about wattage produced in relation to Peak Power Output Gross Efficiency could modify these values, but it adds too much complexity to the model.

Other: in rollers training, a higher tan real time performed can be counted, since cycling is continuous instead of normal no-cycling rests outdoors by uneven roads or drafting. Total energy cost is reduced since total cycling time is lesser tan total workout time. Also, thermoregulation response is clearly harder for indoor cycling (Battista et al., 2008). This value must be considered by the cyclist, being around up a to 20% difference. Thus, for indoor-outdoor comparisons, it could be assumed that 80% of outdoors time would be enough when conducted indoors.

Subjective load quantification criteria

The scale should enable:

- Easy understanding
- Easy identification of maximal and minimal efforts
- Definition of fewer categories for greater reliability

A 0-to-5 scale has been chosen to avoid middle-point values (to force a given trend instead of the typical 0-10 scale). However, 'half-points' can be identified when more accuracy is required.

The justification for **Subjective Load Equivalents** (***ECSs***, for its Spanish initials) will come from biological markers. In fact, we use it to unify training impact following the original proposal made by Bompa (1994). It is impossible to control all factors (training, accumulated fatigue, nutritional status before training) and the different ways to quantify physical capacities (such as strength and endurance). Thus, the 0-to-5 scale can prove useful and suitable for comparison with other particular training variables, with the additional possibility of measuring both daily and accumulated values.

Table 4. *Reference scale for Subjective Load Equivalents (ECSs).*

Value	Daily load type
0	**Rest**
0.5	
1	**Light** total load
1.5	
2	**Medium** total load
2.5	
3	**High** total load
3.5	
4	**Very High** total load
4.5	
5	**Competition**. Also **Exhaustive training** or **Test** as hard as **a competition**

As a general guideline, a training adaptation will be considered appropriate if the objective load increases gradually while the subjective load only increases at the beginning and later becomes flatter, or at least does not increase at the same rate.

ECO and ECS accumulation will depend on each athlete's level and training load, daily stress, recovery strategies and stress tolerance.

It is not our goal to show absolute values, but relative trends. This can also be an easy tool for the coach to compare designed versus reported training load both daily and on a cumulative basis.

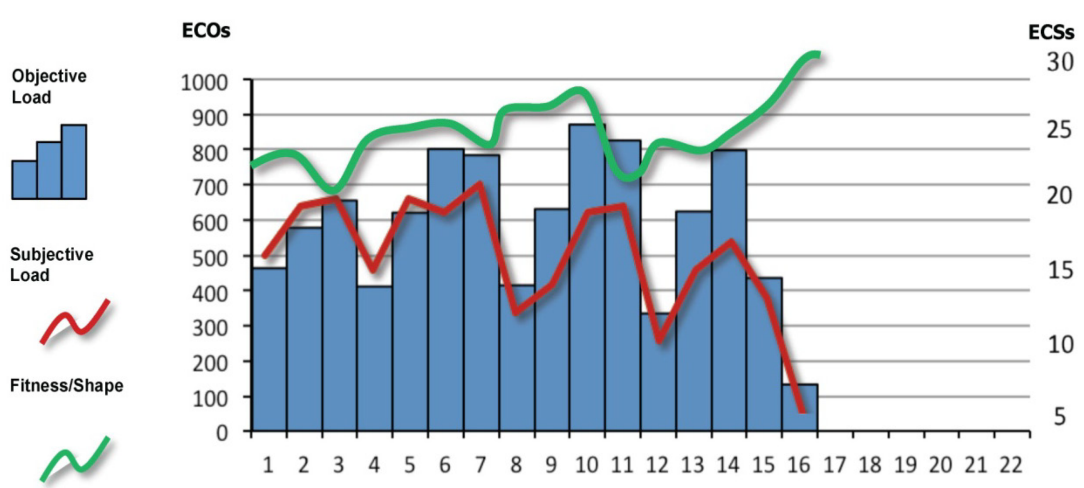

Figure 9. *Sample Trends for Objective load (ECOs), Subjective load (ECSs) and overall performance (theoretically) during a 16-week macro-cycle.*

CONCLUSIONS

In fact, the problem still lies in the universality of quantification, in this case dealing with density in continuous methods in a non-arbitrary way and the joint consideration of various qualities. No easy solution seems to exist for the second aspect beyond Foster's session RPE system, the option for the first aspect being to consider the time limit at each zone and look for coefficients to weight density (which would not be pure density) for the purpose of obtaining equivalences between the hardest workouts, and to find a density coefficient for continuous workouts.

In short, endurance sports like triathlon apparently need much more than the mere count of 'meters or kilometers, or beats, the current quantification methods being still insufficient on their own. Therefore, the best approach can be a combination of those methods according to the sportsman or woman and the specific moment.

It is very important to consider perceived exertion. Various studies have assessed both the effectiveness of this perception (Foster et al., 2001) and its usefulness compared to that of lactate or HR zones in training control (Seiler & Kjerland, 2006).

Perceived exertion has been positively correlated with training quantification by heart rate zones and the training impulse (TRIMP), but the correlation is lower with longer training periods at high or low intensity zones (Borresen & Lambert, 2008).

The Objective Load Scale (*ECO*) as well as the Subjective Load Scale (*ECS*) are easily applied and, together with other verified objective methods, can prove useful for quantifying training in triathlon. These are more specific than previous proposals, although they still need to be scientifically validated.

REFERENCES

1. ACHTEN J, JEUKENDRUP AE. Heart rate monitoring: applications and limitations. *Sports Med.* 2003; 33:517-538. [Abstract] [Back to text]
2. AINSWORTH BE, HASKELL WL, WHITT MC, IRWIN ML, SWARTZ AM, STRATH SJ, O'BRIEN WL, BASSETT DR, SCHMITZ KH, EMPLAINCOURT PO, JACOBS DR, LEON AS. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000; 32:S498-504. [Full Text] [Back to text]
3. BANISTER EW, CALVERT TW. Planning for future performance: implications for long term training. *Can J Appl Sport Sci.* 1980; 5(3):170-6. [Abstract] [Back to text]
4. BASSETT DR, FLOHR J, DUEY WJ. Metabolic responses to drafting during front crawl swimming. *Med Sci Sports Exerc.* 1991; 23:744-747. [Abstract] [Back to text]
5. BATTISTA RA, FOSTER C, ANDREW J, WRIGHT G, LUCIA A, PORCARI JP. Physiologic responses during indoor cycling. *J Strength Cond Res.* 2008; 22:1236-1241. doi:10.1519/JSC.0b013e318173dbc4 [Back to text]
6. BERNARD T, HAUSSWIRTH C, LE MEUR Y, BIGNET F, DOREL S, BRISSWALTER J. Distribution of Power Output during the Cycling Stage of a Triathlon World Cup. *Med Sci Sports Exerc.* 2009; 41(6):1296-1302. doi:10.1249/MSS.0b013e318195a233 [Back to text]
7. BOMPA T. *Theory and Methodology of Training*. Dubuque: Kendall/Hunt; 1983. [Back to text]
8. BOMPA T. *Theory and Methodology of Training*. McGraw-Hill; 1994. [Back to text]
9. BOMPA T. *Periodización. Teoría y metodología del entrenamiento.* Barcelona: Ed. Hispano-

Europea; 2003. [Abstract] [Back to text]

10. BORRESEN J, LAMBERT MI. Quantifying Training Load: A Comparison of Subjective and Objective Methods. *International Journal of Sports Physiology and Performance.* 2008; 3:16-30. [Abstract] [Back to text]
11. BORRESEN J, LAMBERT MI. The Quantification of Training Load, the Training Response and the Effect on Performance. *Sports Med*. 2009; 39(9):779-795. doi:10.2165/11317780-000000000-00000 [Back to text]
12. CEJUELA R, PEREZ-TURPÍN JA, VILLA JG, CORTELL JM, RODRIGUEZ-MARROYO JA. An analysis of performance factors in sprint distance triathlon. *Journal of Human Sport and Exercise*, 2007; 2(2):1-25. [Full Text] [Back to text]
13. CHATARD JC, WILSON B. Drafting Distance in Swimming. *Med Sci Sports Exerc.* 2003; 35:1176–1181. [Abstract] [Back to text]
14. EDWARDS S. *The heart rate monitor book*. Sacramento: Fleet Feet Press; 1993. [Abstract] [Back to text]
15. ESTEVE-LANAO J. El entrenamiento de la fuerza y resistencia en corredores: últimas tendencias y aplicaciones. In: A Jiménez. *Avances en Ciencias de la Actividad Física y el Deporte: Entrenamiento de Fuerza*. Madrid: Escuela de Estudios Universitarios Real Madrid Universidad Europea; 2007. [Back to text]
16. ESTEVE-LANAO J, LUCIA A, DEKONING JJ, FOSTER C. How do humans control physiological strain during strenuous endurance exercise? *PLoS One*. 2008; 13; 3(8):e2943. doi:10.1371/journal.pone.0002943 [Back to text]
17. FARIA EW, PARKER DL, FARIA IE. The Science of Cycling. Physiology and Training – Part 1. *Sports Med*. 2005; 35(4):285-312. [Abstract] [Back to text]
18. FIXX JF. *The Complete Book of Running*. New York: Random House; 1977. [Back to text]
19. FOSTER C, FLORHAUG JA, FRANKLIN J, GOTTSCHALL L, HROVATIN LA, PARKER S, DOLESHAL P, DODGE C. A new approach to monitoring exercise training. *J Strength Cond Res.* 2001; 15:109-115. [Full Text] [Back to text]
20. GARDNER AS, STEPHENS S, MARTIN DT, LAWTON E, LEE H, JENKINS D. Accuracy of SRM and Power Tap Power Monitoring Systems for Bicycling. *Med Sci Sports Exerc.* 2004; 36(7):1252-1258. [Abstract] [Back to text]
21. HAYES PR, QUINN MD. A mathematical model for quantifying training. *Eur J Appl physiol*. 2009; 106:839-847. doi:10.1007/s00421-009-1084-8 [Back to text]
22. HUE O, LE GALLAIS D, CHOLLET D, BOUSSANA A, PREFAUT C. The influence of prior cycling on biomechanical and cardiorespiratory response profiles during running in triathletes. *Eur J Appl Physiol Occup Physiol*. 1998; 77(1-2):98-105. [Abstract] [Back to text]
23. ILIUTA G, DIMISTRESCU C. Criterii medicale si psihice ale evaluarii si conducerii antrenamentului atletitor. *Sportul de Performanta.* 1978; 53:49-64. [Back to text]
24. LAMB DH. *Physiology of Exercise: Responses and adaptation*. New York: MacMillan Publishing Company; 1984. [Back to text]
25. LEWEKE F, BRUCK K, OLSCHEWSKI H. Temperature effects on ventilatory rate, heart rate, and preferred pedal rate during cycle ergometry. *J Appl Physiol.* 1995; 79(3):781-85. [Abstract] [Back to text]
26. LUCÍA A, HOYOS J, CARVAJAL A, CHICHARRO JL. Heart rate response to professional road cycling: The Tour de France. *Int J Sports Med*. 1999; 20:167-172. [Abstract] [Back to text]
27. LUCÍA A, HOYOS J, CHICHARRO JL. Preferred pedaling cadence in professional cycling. *Med Sci Sports Exerc* 2000; 33:1361-1366. [Abstract] [Back to text]

28. MCARDLE WD, KATCH FI, KATCH VL. *Exercise Physiology: Energy, nutrition and human performance.* Philadelphia: Lea & Febiger; 1986. [Abstract] [Back to text]
29. MCCOLE SD, CLANEY K, CONTE JC. Energy expenditure during bicycling. *J Appl Physiol.* 1990; 68:748-753. [Abstract] [Back to text]
30. MILLET GO, VLECK VE. Physiological and biomechanical adaptations to the cycle to run transition in Olympic triathlon: review and practical recommendations for training. *Br J Sports Med*. 2000; 34(5):384-90. doi:10.1136/bjsm.34.5.384 [Back to text]
31. MILLET GP, MILLET GY, HOFMANN MD, CANDAU RB. Alterations in running economy and mechanics after maximal cycling in triathletes: influence of performance level. *Int J Sports Med*. 2000; 21(2):127-32. [Abstract] [Back to text]
32. MIYASHITA M. Method of calculating mechanical power in swimming the breast stroke. *Res Quart*. 1974; 45:128-137. [Back to text]
33. MORTON RH, FITZ-CLARKE JR, BANISTER EW. Modeling human performance in running. *J Appl Physiol* 1990; 69(3):1171-7. [Full Text] [Back to text]
34. PENDERGAST D, ZAMPARO P, DI PRAMPERO PE, CAPELLI C, CERRETELLI P, TERMIN A,CRAIG A, BUSHNELL D, PASCHKE D, MOLLENDORF J. Energy balance of human locomotion in water. *Eur J Appl Physiol*. 2003; 90:377-386. doi:10.1007/s00421-003-0919-y [Back to text]
35. PÉRONNET F. *Maratón.* Barcelona: INDE; 2001. [Abstract] [Back to text]
36. RUSKO HK, PULKKINEN A, SAALASTI S, ET AL. Pre-prediction of EPOC: a tool for monitoring fatigue accumulation during exercise? *Med Sci Sports Exerc.* 2003; 35(5):S183. [Full Text] [Back to text]
37. SEILER KS, KJERLAND GØ. Quantifying training intensity distribution in elite endurance athletes: is there evidence for an "optimal" distribution? *Scand J Med Sci Sports.* 2006; 16:49-56. doi:10.1111/j.1600-0838.2004.00418.x [Back to text]
38. SWEET TW, FOSTER C, MCGUIGAN MR, ET AL. Quantitation of resistance training using the session rating of perceived exertion method. *J Strength Cond Res*. 2004; 18(4):796-802. [Full Text] [Back to text]
39. VERCRUYSSEN F, BRISSWALTER J, HAUSSWIRTH C, BERNARD T, BERNARD O, VALLIER JM. Influence of cycling cadence on subsequent running performance in triathletes. *Med Sci Sports Exerc.* 2002; 34:530-536. [Full Text] [Back to text]
40. VLECK V, BENTLEY DJ, MILLET GP, BÜRGI A. Pacing during an elite Olympic distance triathlon: Comparison between male and female competitors. *Journal of Science and Medicine in Sport*, 2007; 11(4):424-432. doi:10.1016/j.jsams.2007.01.006 [Back to text]
41. WHITT FR, WILSON DG. *Bicycling Science*. Cambridge: MIT Press; 1982. [Back to text]
42. WOOD RE, HAYTER S, ROWBOTTOM D, STEWART I. Applying a mathematical model to training adaptation in a distances runner. *Eur J Appl Physiol*. 2005; 94:310-316. [Abstract] [Back to text]
43. ZAMPARO P, GATTA G, PENDERGAST D, CAPELLI C. Active and passive drag: the role of trunk incline. *Eur J Appl Physiol*. 2009; 106:195-205. doi:10.1007/s00421-009-1007-8 [Back to text]