Original Article

Dynamics of the aerobic and anaerobic threshold in relation to training load in cross triathlon

SVETLANA LIPÁROVÁ¹, JAROSLAV BROŽÁNI²

^{1,2} Department of Physical Education and Sports, Faculty of Education, Constantine the Philosopher University, Nitra, SLOVAKIA

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Abstract:

Physiological indicators say a lot about the preparedness and performance of athletes. We considered the basic parameters to be Vo₂max, AeT, AT, lactate and some others. These athletes' parameters progress throughout the annual training cycle (ATC). The ideal curve representing them graphically has a sinusoidal character. It either rises up or goes down towards the peak of the season according to the specific indicator. We have chosen the following diagnostic indicator – the dynamics (progress) of aerobic and anaerobic threshold of a subject who represents Slovakia in the cross and winter triathlon. Required data were obtained from training logs and on the basis of tests carried out under laboratory conditions. Using a treadmill, we determined the speed according to particular threshold loads (AT and AeT), correlated them with training indicators and subsequently identified dependencies. We observed not only their current impact on performance but also the impact of training indicators. The results we obtained uncovered errors and deficiencies in the subject's training process. We have tried to remove them and choose a more appropriate solution and training schedule.

Key words: cross triathlon, training load, aerobic threshold, anaerobic threshold.

Introduction

Triathlon falls into the category of endurance sports. In addition to the time of racing load, it shares common or at least similar methods, means and style of training with endurance sport as well as the division of the all-year season and its respective conditioning. The basis of the training consists in dosing load intensity and volume in cycles that will, after a period of time, result in the permanent adaptation of the body and thus enhance endurance (Formánek – Horčic, 2003; Misárošová – Mandzák, 2003).

Cross triathlon is a summer sport so the season's peak is equally planned for the summer. The preparatory phase begins in October and continues until the first race at the end of April. The peak of the season is represented by the World, European and Slovak Championships. Other races serve to control the level of an athlete's physical fitness and are a good training method during ATC.

As in most endurance sports, the development of basic endurance (BE) is essential also for cross triathlon and it represents 60-85% of the total training volume. The basic endurance zone comprises 75-85% of the individual maximum, i.e. aerobic metabolism. Continuous training methods are considered to be the most appropriate ones (Neumann et al., 2005).

The basic endurance zone is interconnected with the aero-anaerobic zone, i.e. special race endurance that ranges from 85% up to 95% of the individual speed maximum. It covers 10-25% of the training plan. To develop basic endurance, the continuous intensive and alternating methods as well as an extensive form of the interval method are used.

Strength development is one of the crucial elements in endurance training. Specialised trainings help to develop the appropriate and most loaded muscular areas during the performance. The employed training means should correspond to the structure of the performance (Neumann et al., 2005).

One should bear in mind physiological indicators and the race calendar while planning a long-term training. The realisation of ATC should lead to the planned changes in the body and the development of physical strength. Body adaptation abilities to a given load are limited as each body has its own limits. The greatest task is to choose the appropriate load individually in order to improve fitness and achieve the planned training effect. During training it is essential to gradually increase the load and alternate loading and resting phases, i.e. recovery mesocycles where the load is reduced in order to restore energy. It is impossible for an athlete to deliver the best performances six or more months in a year (Viru, 1986).

Sports periodization - round training loading is inseparable from the recovery of an athlete's body. Fatigue (physical, psychological, overall, peripheral) as a natural consequence of musculoskeletal loading will reduce the activity of the individual functions of the body and therefore lower endurance performance (Dantas, 2003).

Actually, we are dealing here with periodization in long-term sports training. In general, periodization is a detailed time planning in accordance with the firmly fixed objectives of the training and respecting the scientific standards fixed in physical exercises (Dantas, 2003).

After the fatigue phase, a recovery phase must naturally follow (passive or active recovery focused on the resynthesis of energy already during training) leading to the removal of the former. During recovery, not only consumed energy reserves are restored. According to Jakovlev et al. (1962) even greater supplies of energy are created during the supercompensation phase, exceeding the initial level of energetic potential.

There is a certain type of time hierarchy, according to the structure and order of the training load, lasting usually 6-8 weeks. That was also one of the reasons for changing the duration of the mesocycle in sports training in the 1990s. Initially, four weeks were considered to be the optimal duration of the monothematic mesocycle. Today, scientifically controlled trainings use different durations of mesocycles from two weeks to several months, depending on the calendar of competition. Attempting the optimal solution, 6-8 weeks is the minimal duration of the mesocycle in order to achieve more lasting structural changes in the transcription of genetic codes in the human body (Vanderka, 2010).

Top athletes get into shape in 18-22 weeks. This period should be followed by a break in the intensity and recovery phase (Verkhoshansky, 2007).

Matveyev (1992) calls it the basic principle in the training process. The transition phase, increased volume and reduced intensity during ATC are integral parts of ATC training structure.

Both authors agree on that, however, they both have their own theory of periodization in ATC.

Matveyev (1992) promotes one-peak season, the classic training model characterized by regular load increasing and reducing. ATC is divided into a preparatory, racing and transition period.

This model is useful in the Olympic and World Cup year, when the athlete is preparing exclusively for one event and other races are only part of the training process.

Contrary to this, Verkhoshansky's theory (2007) allows more peaks in a season, which is more practical and advantageous for today's athletes as they want to succeed in several championships. It is a training model divided into blocks or periods. ATC is divided into periods A, B and C. The first period is the accumulation phase. Period B is the transformation period and the last one is the racing period.

Plisk and Stone (2003) agree with the authors (Matveyev, 1992; Formánek, Horčic, 2003; Neumann et al., 2005; Verkhoshanski, 2007) in the training orientation. It is focused on alternating the phase of high volume with low intensity gradually changing into the phase of opposite character - low volume and high intensity. In general preparation, volume training predominates, receding in the racing period and continually decreasing (Fig. 2). At the beginning of special preparation the technique is progressively trained more and more until the active recovery phase (transition period). From the beginning of the racing period, intensity increases, reaching the maximum at the peak of the season. The next period is typical of a distinctive drop in intensity. After the season, in the period of active rest, all three components decline.

There is currently no universal structure of sports training and many leading experts (Fomes, 2003; Plisk – Stone, 2003; Verkhoshansky, 2007; Bompa – Haff, 2009; Verkhoshansky – Siff 2009) point to the defects of the theories from the 1960s as they were only partially verified by research.

In the short term, a classical linear periodization seems to be more suitable for beginners and youth.

Another model of ATC division is similar to Plisk – Stone's (2003). It is characterized by a predominance of the volume at the beginning of the preparatory period. It goes gradually down and yields to the intensity and technique of movement. Both practice indicators culminate in the transformation (racing) period. Approaching the transition period, they decline and join the level of volume load.

Bompa – Haff (2009) have a similar, one-peak training model. Throughout the training, the volume parameter (unbroken line) decreases towards the peak with mild rises. The highest volume load is in the preparatory period, mesocycle 3-4. On the contrary, the intensity increases until the racing period and decreases afterwards. The trainings with the highest intensity (maximum % of VO₂max) take place in the mesocycle 5-8, so 3-6 mesocycles before the peak of season.

The season with two peaks, in the winter and summer part of ATC, is slightly more complicated. The first preparatory period should last 3 months (Bompa – Haff, 2009). It helps the athlete to acquire general and consequently specific endurance. It is actually the period of accumulation and intensification, followed by the transformation period lasting two and a half month and aiming to prepare the athlete and "polish" his/her condition for the peak events in the winter part of ATC. The race is followed by a short transitional period lasting about 1-2 weeks. Afterwards, a two-month additional preparatory period (II) ensues, shorter than the first. Here the training is concentrated on more specifically as basic endurance shall have been acquired in the winter part of the preparation. The summer racing period is longer, lasting three and half months. During this time, the athlete should prepare him/herself for his/her second ATC peak.

The character of the volume and intensity of the load resembles stairs that change during the season.

According to Bondarchuk (1988), the intensity and volume load have a rather sinusoidal shape. Once the volume load decreases, the intensity climbs up to the peak of the season. After the summer part of ATC, the volume stays down and the intensity is no longer applied.

Tschien's (1989) ATC course has a constant sinusoidal shape. The volume alternates with the intensity. In the winter part of ATC, the volume curve is above the intensity curve and they have an identical shape. In summer preparation, the volume curve drops under the intensity curve but they still have the same shape, e.g. the greater the volume, the greater the intensity. This training model is not currently very efficient.

Many authors (Berger, 1980; Platonov, 1980; Žukov, 1983; Choutka – Dovalil, 1987; Košťál, 2001; Belás, 2006; Moravec, 2007; Šimonek, 2007; Killing – Rinder, 2009; Laczo, 2011; Laczo, 2012) discussed the issue of the intraindividual assessment of training load and its impact on performance. However, their works were based on interindividual research. They observed athletes differing in somatic and physiological parameters and tried to generalize the obtained results for a larger group of top athletes.

Berger (1980) and Schnabel (1982) point out the changes of the performance in relation to the training loading.

Pataki et al. (1982) compared intra-individual and inter-individual analysis with the result confirming the benefits of methods of intraindividual analysis concerning the peculiarities of performance.

In their studies, Havlíček (1977); Havlíček – Záhorec (1983); Hutňan (1987); Vindušková (1987); Kolčiter (1993) used correlation and regression in the analysis of time series. They watched the athletes "ex post facto". They found out that this method is suitable for modelling the training load.

Vavák et al. (2008) dealt with the "ex post facto" intraindividual assessment of a high jumper. They took into consideration only those general training indicators they had good access to. They correlated them with the performance.

Seidl – Pupiš – Suchý (2014) were interesting in Specific vs. non-specific performance tests in triathlon – swimming. They found very strong correlation between them.

Tirre – Raouf (1998) and Langendorfer – Robertson (2002) claim that differentiation between genetic factors and those that can be further developed does not guarantee their use in training practice.

Method

Participants

The subject represents Slovakia in cross and winter triathlon. He regularly takes part in international races (World and European Championships) and also national races in sprinting, Olympic and half-ironman tracks. He began his career in sports as a swimmer in the Žilina swimming club– Nereus Žilina. This club participated in the formation of the triathlon club under the same name. Their swimming coach was P. F. As a swimmer, he has excellent triathlon fundamentals.

T. J., born in 1983, is 179 cm tall with an average weight of 74 kg. He has been engaged in triathlon for 12-13 years. As mentioned above, he represents the swimming and triathlon club Nereus Žilina. He prepares his training plan by himself. He trains with his training group under his own professional guidance. During the winter training, he cooperates with M.S., athletics and national coach for the winter triathlon and cross triathlon from Banská Bystrica.

T. J. won the Slovak Cup 2011 in winter triathlon. He finished second in the cross triathlon in the Slovak Championship. He is the 2012 Champion of Slovakia in winter as well as in cross triathlon. In 2012, he finished third at the European Cup Winter Triathlon in Switzerland and fourth in Estonia. He finished seventh at the World Championship Winter Triathlon; however, he could not finish the race at the European Championship Winter Triathlon due to technical reasons. He finished eighth at the European Championship Cross Triathlon (the Hague, the Netherlands).

In 2013 at the European Championship Winter Triathlon, he came in sixth place due to a 15-second penalty; otherwise, he would have ended fourth. At the World Championship Winter Triathlon he won the ninth place in his category and he ended tenth in the overall standings. He carried off the silver medal at the 2013 Czech Republic Championship and the gold medal at the 2013 Slovak Championship, both for the winter triathlon. He took sixth place at the 2013 Cross Triathlon World Cup and fifth place at the 2013 European Championship. In 2013, he was the Slovak Champion in the cross triathlon. In 2013, he was awarded the title of Slovak Champion in the sprint-distance triathlon (0.75 – 20 – 5 km) and he ended second in the Olympic-distance triathlon. In half-ironman track in St. Polten he won the second place in his category, which made him the most successful Slovak on the track.

Our research had an intraindividual character and was carried out "ex post facto". The subject was a mountain triathlete.

The test period – the annual training cycle (ATC) 2011/2012 and ATC 2012/2013 – comprised 26 four-week mesocycles. The annual training cycle 2011/2012 lasted from 12 September 2011 to 9 September 2012 and the other, ATC 2012/2013, from 8 October 2012 to 6 October 2013.

The training stimuli are composed of specific training load indicators.

To evaluate the data, we used the method of a training log assessment, therefore we studied the triathlete's training log from 2011/2012 and 2012/2013. In order to collect information about the training load in particular bio-energetic H1-H3 zones, the GARMIN system was employed. When specifying the training

methods, we respected the basic condition of equidistant numerical data regarding the quantitative and qualitative aspects of the training load during individual periods in relation to the conditions underlying the methods used for data processing and evaluation.

The annual results of the function and the lactate tests (4x2 km) represent the criterion of physiological performance ("Y" – dependant variables). Both tests were carried out on the HP COSMOS treadmill PULSAR 4.0/QUASAR. The function tests were carried out under laboratory conditions in the Institute of Special Health Care and Training of the Ministry of Defence of the Slovak Republic in Lest. The lactate tests were also done under laboratory conditions at Matej Bel University in Banská Bystrica. We focused on values regarding the anaerobic (AT) and the aerobic (AeT) threshold in relation to speed ($v = m \cdot s^{-1}$), heart rate ($HR = n \cdot min^{-1}$), lactate ($mmol \cdot l^{-1}$), workout load (W), oxygen uptake ($\% VO_{2max}$), and energy delivery (%).

As soon as the testing is finished, we can observe a decrease in pulse rate and thus assess the regenerative abilities of the body (Casri, 2012).

The importance of the workout load and better sport performance increases with the collection and transfer of knowledge to other scientific fields as well as with experiments concerning a specific sport in specific conditions (Kellmann, 2002).

To obtain particular values of the training methods ("X" – independent variables), we chose general as well as specific training indicators used equidistantly in training practice in relation to age (Tab. 1). The training and the racing loads were recorded during the individual training cycles. In our study, we used mesocycles consisting of two 7-day cycles.

Table 1. General and Specific Training Indicators in Cross Triathlon

		Training Indicators
General Indicators (GTI)	Training	Load Days [n]
		Load Time [h]
		Training Units [n]
		Number of Starts [n]
		Recovery [h]
		Swimming [km]
		Swimming [h]
		Swimming H1 [h]
		Swimming H2 [h]
		Swimming H3 [h]
Special Training Indicators (STI)		Cycling [km]
		Cycling [h]
		Cycling H1 [h]
		Cycling H2 [h]
		Cycling H3 [h]
		Running [km]
		Running [h]
		Running H2 [h]
		Running H3 [h]
		Running H4 [h]
		Other [h]
		Fitness [h]

Results

Both macrocycles are divided into twenty-six 2-week mesocycles. The first ATC 2011/2012 lasted from 12 September 2011 to 9 September 2012.

The other ATC started on 8 October 2012 (one-month break/transition period due to injury) and ended on 6 October 2013.

Both RTCs were of the subject's two-peak season with the winter peak in mesocycle 13 and 14 in the first ATC (European Winter Triathlon and World Championships), in mesocycle 8 and 10 in the second ATC. In the summer part of ATC 2011/2012, peak season was targeted on the European Championship Cross Triathlon (mesocycle 22) and in the following ATC 2012/2013 on mesocycles 20 and 24 (European and World Championship Cross Triathlon). The subject did not participate at 2012 World Championship Cross Triathlon due to the high costs, which he would largely have had to pay himself.

Figures 1- 6 display the progress of AeT and AT curves in relation to volumes as carried out by the subject in the individual zones of particular disciplines.

Fig. 1. Dynamics of Training Load and Physiological Thresholds in 2011/2012 ATC in zone H1

Fig. 2. Dynamics of Training Load and Physiological Thresholds in 2012/2013 ATC in zone H1

In the first ATC, the AeT and AT curves have sinusoidal shape with opposite progress. The AeT curve follows the volumes in zone H1 (Fig. 1). It rises up at higher volumes and goes down when the volumes decrease. The AT curve has exactly the opposite progress. With regard to curves, winter training is ideal in this year. During the winter peak season (mesocycle 13-14), the AT curve culminates and the AeT curve is in contrast to the former, in the lower part of table. The subject succeeded in maintaining this flawless progress of curves only in the 2011/2012 winter season. The volume in zone H1 in summer training is unnecessarily high in mesocycle 21. The AT curve rises up (and the AeT goes down) only during the European Championship Cross Triathlon. In the second year, the AeT curve continually grows even when the volumes get lower (Fig. 2). The AT curve stagnates at the lowest level of the years 2011/2012. It only starts to rise up markedly at the end of the season with a lower volume in zone H1. In the summer part of 2012/2013 the training volume in zone H1 is also quite high as in the former season. The AeT curve responds to a high volume load in zone H1 by its continual growth throughout the season.

Fig. 3. Dynamics of Training Load and Physiological Thresholds in 2011/2012 ATC in zone H2

Fig. 4. Dynamics of Training Load and Physiological Thresholds in 2012/2013 ATC in zone H2

Figures 3 and 4 illustrate that the zone H2 influenced mainly the growth of AeT curve in both ATCs. It is evident especially in the summer parts of the season, when the AeT curve rises up with increased volume load. Contrary to AeT, AT curve rises up in this zone only when the volume load decreases. In the winter training, it is the case of mesocycle 12-13 (2011/2012) and mesocycle 10-11 (2012/2013). In the summer training, the volume load decreases in zone H2 in mesocycle 22, 24 and 26 (2011/2012) and in mesocycle 22-24 (2012/2013). Here the AT curve starts to rise up again.

Fig. 5. Dynamics of Training Load and Physiological Thresholds in ATC 2011/2012 in zone H3

Fig. 6. Dynamics of Training Load and Physiological Thresholds in ATC 2012/2013 in zone H3

It seems that zone H3 is a factor that does not affect the progress of the aerobic threshold and the AeT curve (Fig. 5, 6). The high volumes in this zone have negative effects on the AT in both seasons. When considerably high volumes are set in this zone, the AT curve tends to go down. From Fig. 5, 6, we can assess that in both seasons, volume loads up to 2h/mesocycle (2 weeks) make the AT curve rise. The high volume load in zone H3 or rather the unsuitable periodization had a probably negative impact on the AT in 2012/2013 ATC. This phenomenon was pointed out in the work of Brožáni – Tóth (2013), where a higher volume load in intensive special endurance had a negative impact on sports performance in 20 km and 50 km racewalking.

After the first observed year, we tried to adjust the subject's following ATC on the basis of recommendations of volume indicators for a two-peak season (Bondarchucka, 1988; Formánek – Horčic, 2003; Neumann et al., 2005; Bompa – Haff, 2009). That includes lowering the volumes in zone H1 towards the peak of the season and contrariwise; and increasing volume indicators on zones H2 and H3 towards the periods of

intensification and transformation; and also concentrating on accuracy improvement of volume indicators in all zones of the ATC. In the winter accumulation period, we shall prefer zone H1 (two and a half month), progressively pass over the intensification phase in racing period and move up to the peak of the winter part. The first transition period, which is inevitable and where the subject should do his best even at the expense of being absent at less important Slovak races, is followed by the accumulation period. It should be slightly shorter, one and a half or two months. In the summer training, the intensification period starts, as it is assumed that the subject has enough volume parameters from the winter training. Consequently, the transformation and competition period are longer (three or three and a half months) leaving enough time to fine-tune for the peak of summer season. In the first year of winter training, the subject had three months of accumulation, two months of intensification and two months of transformation. With regard to the AeT and AT curves, the adjustment was ideal and complied with regulation (Formánek – Horčic, 2003; Neumann et al., 2005; Bompa – Haff, 2009). In the 2012/2013 ATC we did not stick to the model because of the subject's injury at the beginning of the preparatory period. The accumulation period started later and thus it was shortened in order to tune up for the winter peak of 2012/2013. Intensification and transformation periods were effectuated according to the plan. The subject improved with regard to the performed volumes in individual zones in percentage terms (accumulation 90%, intensification 6.5%, and transformation 3.7%) Unfortunately, the volume indicators are lower almost by half compared to the previous season: 2011/2012. The volumes in zone H3 equalized only during the transformation period (6.7h in the first ATC, 5.8h in the second ATC).

In the summer of 2011/2012, the accumulation period lasted one and a half months, the intensification period two months and the transformation period three months. Here the intensification period could have been a bit shorter. In the second ATC, the subject tried to make up for the loss during the winter training, therefore, the accumulation period lasted two months. The intensification period had the same duration and it was followed by a four-month competition and transformation period. In the 2012/2013 summer training, volume indicators were higher (334h – 81% of accumulation, 53h – 12.7% of intensification, 17h – 4% of transformation) compared to the previous season (249h – 84% of accumulation, 36h – 12% of intensification, 11h – 3.6% of transformation). In terms of percentage, both trainings conform to the standard (Formánek – Horčic, 2003; Neumann et al., 2005) and they are quite similar. However, none of them recorded the rise of the AT curve nor the rise of endurance.

Although the subject increased the volume in zones H2 and H3 in the second ATC in terms of percentage by increasing the volume in zone H1, it was not sufficient to make the AT curve rise. Keeping the same volume in zone H1 (from the 2011/2012 season) and increasing the volumes of zones H2 and H3 should lead to the rise of the AT curve. The subject has still a lot to do in the periodization of ATC. The curves might have looked differently if he had stuck to the training from the winter part of the 2011/2012 season and adjusted the volume indicators and periodization in the summer part. These changes could help him to raise the anaerobic threshold (increasing speed) and increase performance. For the next years, we would recommend him to follow the winter preparation from 2011/2012 ATC despite the high volume in zone H1 compared to zones H2 and H3; and primarily adjust summer preparation, e.g. shorten the accumulation period with a lower volume in H1 and increase the volume of zones H2 and H3 afterwards.

Discussion and conclusions

Despite the partially improved periodization of specific training indicators (STI) and correct percentual volumes in individual zones, the subject attained worse results in the second ATC, in terms of AT. The reason may be the injury at the start of the 2012/2013 preparatory period. It induced a lower volume in the accumulation period and consequently, the intensification and transformation period were less successful too as the volume was not set high enough for further development. Despite changes in the second ATC, the greatest deficiency in the preparations is the high volume loads in the aerobic zone throughout the training cycle and the irregular, unsystematic managing of the anaerobic zone which, statistically, had almost no impact on AeT and AT.

On the basis of these facts we tried to boost the efficiency of the training process by changing the periodization of specific training indicators in ATC 2012/2013. After the first year, we advised the subject to follow the recommended parameters in zone H1 according to the model of the 2011/2012 winter training, e.g. set the training volumes in a way that the volumes in the aerobic zone reduce as we near the peak of the season. The volumes in the other two zones must have exactly the opposite progress as in zone H1. They should increase steadily towards the peak of the season. The volume in zone H3 should be one-third lower compared to the volume in zone H2. The latter shall represent 15-30% of the overall volume load (Formánek – Horčic, 2003; Plisk – Stone, 2003; Neumann, 2005; Verkoshansky – Siff, 2009). The 2011/2012 ATC is marked by the subject's high percentual proportion of volume in zone H1 (87%), only 9% in zone H2 and 3% in zone 3 (one-third of H2 obeyed). Thus the subject did not achieve the prescribed percentual volume load in the three zones at all. Our aim for the following season was to decrease the volume load in zone H1 and increase the volumes in the mixed and anaerobic zones. We partially succeeded. The results were 83% in the aerobic zone, 11% in zone H2 and 4% in the anaerobic zone. Percentual values are slightly better than in the first ATC, but they still do not comply with the recommended figures. The aerobic zone is built too slowly in the intensification and transformation period, too. Both zones are lacking more intense speed force training (Jakovlev, 1962; Plisk – Stone, 2003; Verkoshansky – Siff, 2009).

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