Training Characteristics of Male Junior Cross Country and Track Runners on European Top Level

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ABSTRACT

The purpose of the present study was to describe training characteristics of distance junior runners at European top level. The athletes' training diaries for the 2008 season were analysed. The total training volume (km/week) performed over the different training periods was registered on five differentiated intensities. The results showed that during the building-up period for the season the junior runners ran an average of 132.5 ± 25.9 km/week. 78.3 ± 4.7 % of their weekly training distance (km/week) was continuous running with a heart rate (HR) between 62-82 % of maximum. During the track competition season the total weekly running distance was 115 ± 22.9 km/week. The training in the three last months before the European Cross Country Championship was very similar to the training in the building up period. In 2008, three of four tested $\dot{V}O_2max$, and the average was 79.2 ± 4.8 ml • kg^{-1} • min^{-1}.

Key words: Anaerobic Threshold Training, Blood Lactate, Distance Running, Heart Rate, Oxygen Uptake, Principles of Training

INTRODUCTION

The question of how to organize daily training to improve aerobic capacity in elite junior endurance athletes is a debated topic among coaches and researchers throughout the world, and several attempts have been made to construct a model of optimal endurance training[1,2]. In a training program for long-distance runners, the most essential exercise variables are training volume (km/week), training frequency (training units/week) and intensity distribution measured in percent of maximum heart rate (% HR_{max}) or in percent of $\dot{V}O_2max$ (% $\dot{V}O_2max$)[3,4,5]. A consensus of how these parameters should interact to be optimized, however, remains elusive[6,7].

The research literature indicates three different basic models of training quantification and intensity distribution for elite endurance athletes[8,9]. A low intensity – high volume training

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model emerges from a number of published observations of international rowers, cross country skiers, orienteering runners, cyclists and elite long-distance and marathon runners, suggesting that 80-85 % of the total training volume (km/week) should be executed with an intensity below the anaerobic threshold and 15-20 % of the training volume clearly above the anaerobic threshold[2,4,10-14].

A review of the literature shows that the most successful long-distance runners do a work load between 150-200 km/week during a training year[10,15,16]. Estavo-Lanao et al.[17] analysed the total training volume of eight regional Spanish runners (23-28 years) over a period of six months leading up to the Spanish Cross Country Championship. The best performance in 1500m and 5000m track races averaged 85.8 % and 82.1 %, respectively, of the world record. The study showed that athletes on a regional level performed 70-80 % of their training with low intensity (< 60 – 70 % of HR_{max}), 10-20 % of the training with moderate intensity (70 – 85 % of HR_{max}) and 8-10 % with high intensity (85-100 % of HR_{max})[17,18].

The anaerobic threshold training model (training at the individual anaerobic threshold pace (vAT)) observed both through training practice and investigations, is beneficial for the aerobic training response[19,20]. Some studies argue for the relevance of greater training volume at intensities around the anaerobic threshold[21-23]. Simoes et al.[24] suggest that the moderate intensity domain can be sustained without lactate accumulation and may be used for long-term running exercise. Several studies indicate that training done at an intensity of 82-92 % of HR_{max} (80-87 % of $\dot{V}O_2max$) is favourable in order to improve performances in long-distance running[25-27]. Kenyan runners also do a lot of training at this intensity[28]. Billat et al. reported increased $\dot{V}O_2peak$ in elite marathon runners as a result of more training at marathon pace which is close to vAT[29].

Some studies have also demonstrated increased $\dot{V}O_2max$ in athletes when a high-intensity training model replaced training performed at low- and moderate intensities[29,30]. Other studies that incorporated training intensities of 90-100 % of $\dot{V}O_2max$ reported similar but insignificant increases in $\dot{V}O_2max$[31-34]. In a study of moderate trained athletes, Helgerud et al.[35] found that aerobic high-intensity training improved $\dot{V}O_2max$ more than moderate training. Acevedo and Goldfarb[36], however, reported that inclusion of training close to $\dot{V}O_2max$ did not enhance $\dot{V}O_2max$ in well trained distance runners. Studies by Burgomaster et al.[37] and Berger et al.[38], found similar metabolic adaptations in untrained persons, when intensive interval training was compared with traditional endurance training over a period of six weeks.

There is a continuous debate among coaches and researchers as to how the training process should be organized to combine the training components needed to improve performance in endurance events. To increase our knowledge of long-distance training and performance, more longitudinal studies are needed to describe how training volume and intensity distribution have to interact in a training program to optimize performance[7,39]. Presently no studies have examined the complex combination of high volume of low intensity combined with high volume on relatively high intensity in the different training- and competitive periods of a macro-cycle (a year). There is a need for more data from field conditions and competitions rather than laboratory testing.

The aim of the present study is to bring forward supplementary information about the total training volume (km/week), training frequency and intensity distribution of four male European top level junior distance-runners during the building-up period, the track competition season and the cross country competition season.

METHODS

SUBJECTS

Four junior male long-distance runners (17.8 ± 1 year) who won the team competition in the Nordic Cross Country Championship in 2008 volunteered to participate in the study. The athletes came second in the team competition in the European Cross Country Championship in 2008; finishing 2nd, 10th, 16th and 23rd. One of the runners was Junior World Champion in mountain running in 2008, and one was Norwegian Junior Champion in cross-country skiing. The personal records, all set in 2008, for the participants were; 1500m (n = 4) 3:55.10 ± 3.00 sec, 3000m (n = 4) 8.19:01 ± 4:99 sec and 5000m (n = 3) 14:29.98 ± 21.23 sec. Including the 2008 season, the participants had been doing serious distance training for 4 ± 1.9 years. All participants gave their written, voluntary consent.

INDIVIDUAL TRAINING DIARIES

Each athlete was asked to send in his training diary for 2008 to be analysed. The training registration protocol in the present study was established based on the intensity zones and duration of training recommended by the Norwegian Olympic Training Centre[40]. Tables 1 and 2 indicate five standardized intensity-zones defined in terms of % of maximum heart rate (% of HR_{max}), blood lactate concentrations, racing speed and duration of training sessions.

Table 1. Lactate, HR in % of HR_{max} and Effect of Training in Different Intensity Zones

Training zone / kind of training	Lactate (mmol/l) LT-1710	HR in % of HR_{max}	Effect
1: Easy and moderate running	0.7-2.0	62-82 %	Running economy
2: Marathon and half-marathon pace	2.0-4.5	82-92 %	Anaerobic threshold marathon pace
3. 10000m-3000m pace	4.5-8.0	92-97 %	$\dot{V}O_2max$ / aerobic capacity
4: 1500m-400m pace	above 8	97-100 %	Anaerobic capacity
5: Sprint / strides			Speed

Table 2. Average Total Running Distance in km/week, and Average Running Distance in Different Intensity Zones, in the Building-Up Season, the Track Competition Season and in the Cross Country Season

	Building Up Period (January-April)	Track Competition Season (May-August)	Cross Country Season (September-December)
Total km /week^{-1}	132.5 +/- 25.9 km	115.1 +/- 22.9 km	145 +/- (22.9 km)
Zone 1 (62-82 % of HR_{max})	103.5 +/- 20.4 km (78.3 +/- 4.7 %)	93.4 +/ 16.7 km (81.4 +/- 3.9 %)	113.3 +/- 23.2 km (78.1 +/ - 6.9 %)
Zone 2 (82-92 % of HR_{max})	26 +/- 9.8 km (19.6 +/-5.4 %)	13,5 +/- 6.8 km (11.7 +/- 3.3 %)	26 +/- 9.2 km (17.9 +/- 5.9 %)
Zone 3: 10000-3000m pace	2 +/- 2,1 km (1.3 +/- 1.4%)	5.5 +/- 3.3 km (4.8 +/- 3.2 %)	4.3 +/- 3.5 km (2.9 +/- 3.5 %)
Zone 4: 1500m-400m pace	0	1,4 +/- 1.2km (0.9 +/- 1.3 %)	0
Zone 5: sprint / strides	1 +/- 1 km (0.5 +/- 0.2 %)	1,3 +/- 0.4 km (1.2+/- 0.5 %)	1.4 +/- 0.5km (1 +/- 0.3%)

The training data reported in the diaries were thoroughly calculated trying to estimate: a) the average number of training sessions for the preparation period (January-April), the track competition season (May-August) and the cross country competition season (September-December); b) mean training volume (km/week); c) distribution of training on the prescribed intensities (% of HR_{max}); d) the average number of continuous running sessions and interval workouts executed at the prescribed intensities in % of HR_{max}; and e) the number of weekly sprint and strength training workouts. In order to describe the training more in detail, weekly training program from the track competition season for two of the athletes are presented to give examples of the performed training volume and intensity distribution of the runners (Tables 3 and 4).

Table 3. A Training Week in the Track Competition Season (June) for Runner A

Day	Am	Pm
Monday		18 km easy continuous running + general strength training
Tuesday	14 km easy continuous running	16 km progressive running (75-90 % of HR_{max})
Wednesday	13 km easy continuous running	19 km easy continuous running
Thursday	10 km easy continuous running	Warm up 4 km+6x80m strides+ +20x400m (10000m /5000m pace), recovery 100m jog + 4 km jog
Friday		19 km min easy continuous running +8x60m sprint and drills + general strength training
Saturday	12 km progressive running (80-90 % of HR_{max})	Warm up 4 km +7x2000m (90 % of HR_{max}), recovery 60 sec jog + 4 km jog
Sunday	26 km easy continuous running	

Table 4. A Training Week in the Track Competition Period (June) for Runner D

Day	Am	Pm
Monday	6 km easy continuous running	7 km easy continuous running + 4 x 80m strides
Tuesday	4 km jog + 4 x 100m strides	(30min warm up + strides) **1500m competition; 3:51.56 (PB)** (20 min jog + strides)
Wednesday	9 km easy continuous running	13 km easy continuous running
Thursday	9 km easy continuous running	20 min jog + drills/strides + 3 x 2x200m (26.5- 28.3). recovery: 200mjog, 400m jog between sets + 15 min jog
Friday	7 km easy continuous running	10 km easy continuous running + 4 x 90m strides
Saturday		11 km min easy continuous running
Sunday	7 km easy continuous running	20 min warm up + drills + 8 x1000m, 90 % of HR_{max} (3:33 – 3:19), recovery 60 sec + 6 x100m strides + 18 min jog

The athletes were told by their coaches to use heart rate (measured by Polar Sport tester S610, Polar Electro OY, Kempele, Finland), speed (min/km) and lactate samples for calibrating the speed during interval sessions and hard continuous runs. Three of the athletes used heart rate monitors on all their training, the fourth now and then. Training performed at intensities of around 90 % of HR_{max} (85 % of $\dot{V}O_2max$) was referred to as the anaerobic threshold intensity as well by the subjects as their coaches. Measurements of Norwegian elite endurance athletes' individual anaerobic threshold during the last 30 years, show that HR at vAT is in this area[40]. They all reported lactate measured at this intensity by Lactate Pro LT – 1710™ (ArkRay, Inc., Koyota, Japan) to be in the area from 2.0 to 4.5 mmol. The identification of heart rate at the anaerobic threshold made it possible to quantify the amount of training performed in each intensity zone. Lactate and HR on interval workouts and continuous running were systematically controlled on monthly national training camps.

$\dot{V}O_2max$ TESTS

After 30 to 40 min warm-up, the athletes performed the $\dot{V}O_2max$ tests on a treadmill (Woodway ELG 2, Weil am Rhein, Germany). To equalize the lack of air resistance on the treadmill compared to running on the track, an inclination of 1.7 % was used. The oxygen uptake was measured through a two-way mouth piece (Hans Rudolph Instruments USA) and a sling connected to O_2 and CO_2 analyzer (Vmax 29 sensor, Medics Corporation, Yorba Linda, CA, USA). To monitor heart rate (HR), a pulse transmitter (Polar Sport Tester S610, Polar Electro OY, Kempele, Finland) was attached around the participant's breast. The pulse belt sent HR signals to a pulse watch (Polar Accurex Plus, Polar Electro OY, Kempele, Finland). The test was initiated with a 5-min period of 11 km/h to ensure stable baseline ventilator measurements, followed by 1 km/h increase in velocity every 30 sec until the athlete reached a speed he felt he could sustain for two more minutes. From here, he ran to exhaustion. $\dot{V}O_2max$ was defined as the highest 60-s average achieved during the test.

STATISTICAL ANALYSIS

Data are presented as means ± standard deviation. The validity of data is shown through the systematic detailed descriptions, the process of analyses and the results.

RESULTS

$\dot{V}O_2max$

Test results of three of the four runners in this study show that $\dot{V}O_2max$ was 79.2 ± 4.8 ml • kg^{-1} • min^{-1}.

FREQUENCY OF TRAINING

During the building-up period, the athletes reported an average of 11 ± 2 training sessions. In the track competition season and cross country season, the average number of training sessions was 10 ± 2 and 11 ± 2, respectively.

COMPETITIONS

The athletes took part in 23.8 ± 6.8 track or cross country races.

MEAN TRAINING VOLUME

During the building-up period, the athletes reported an average of 132.5 ± 25.9 km/week (Table 2). The total training volume was reduced in the track competition season to 115 ± 22.9 km/week. In the cross country season, the training volume was reported to be at a little higher than in the building-up period (145 ± 22.9 km/week).

INTENSITY DISTRIBUTION

Building up period

78.3 ± 4.7 % of their weekly training distance (km/week) during the building up period was continuous running with a HR between 65-82 % of HR_{max} (Zone 1 in Table 2). 19.5 ± 5.4 % of the training volume was done as anaerobic threshold training with a heart rate between 82 and 92 % of HR_{max} (Zone 2 in Table 2). The training reported in Zone 2 (Table 2) is mainly interval sessions, but some hard continuous runs are also included. The athletes did from two to four sessions per week in Zone 2. The number differed from one week to another according to the planned training structure. The total distance run in the different interval sessions carried out in Zone 2 (warm up and jog down are not included) was between 8 and 14 km (26 to 47 min).

Only 1.3 ± 1.4 % of the total training volume in this period was reported to be between 92 and 97 % of HR_{max} (Zone 3 in Table 2). 0.5 ± 0.2 % is reported to be strides or speed training (Zone 5 in Table 2).

Track competition season

In the track competition season, less training is carried out as anaerobic threshold training. The amount of training at 10000m, 5000m and 3000m race pace (aerobic capacity training) and competitions on these distances, however, listed in Zone 3, has increased from 1.3 ± 1.4 % in the building up period to 4.8 ± 3.2 % in this period. Training at 800m and 1500m pace (anaerobic capacity training) and competitions on these distances are 0.9 ± 1.3 % of the total running volume and listed in Zone 4.

Cross country competition season

As we can see from Table 2, the training in the cross country competition season is very similar to the training in the building-up period. The total running volume (km/week), however, is higher. The volume reported in Zone 3 is also higher. This is due to the fact that cross country competitions over distances from 5 to 8 km are listed in this zone.

SPEED AND STRENGTH TRAINING

All four runners reported some kind of general strength training. This training was not specified in detail in their training diaries and is not listed in Table 2.

DISCUSSION

TRAINING VOLUME

The four young distance runners in this study made great progress on all track distances and competed well in cross country competitions in 2008. According to the literature, this improvement may be due to the high training volume (km/week) at low intensities (62-82 % of HR_{max}), performed both in the building-up period and in the competition seasons[12,41]. They ran an average of 11 ± 2 sessions and a mean volume of 132.5 ± 25.9 km/ week, and 10 ± 2 running sessions and a mean volume of 115.7 ± 22.9 km/week in the building-up period and track competition season, respectively. In the cross country season, they ran 11 ± 2 sessions and a mean volume of 145 ± 22.9 km/week. The average weekly distance run over the 6-month period for the subjects in the study of Estavo-Lanao et al.[17] was 70 km/week. This is far below the average running distance of the subjects in the present study. It is primarily the number of km/week spent at low intensities that is the great difference. According to the suggestion in the study of Estavo-Lanao et al.[17], the total training time spent at low intensities might be associated with improved performance. This may be one of the reasons why the subjects in this study, even if they are younger (17.8 ± 1 year versus 23 ± 2 years), performed better than the subjects in the study of Estavo-Lanao et al.[17]. While the best performance of the athletes in 1500m and 5000m track races in the Spanish study[17] averaged 85.8 and 82.1 %, respectively, of the word record, the runners in this study averaged 87.7 and 87.0 % of the word record on the same distances.

It has to be emphasized that the young runners in this study performed a total volume (km/week) which is higher than the observed training in previous studies of young elite cross country skiers[2] and middle- and long-distance runners[10,17,18,42].

From the literature, we know that the traditional low intensity training model (62-82 % of HF_{max}) performed with a total running volume of 150-200 km per week can lead to very good results for long-distance runners who have provided progression in training loads over many years. This model emerges from observations of outstanding distance runners over the last 5 decades[15,16,43].

The marked improvement of the junior distance runners during the building-up period and the competition seasons shows that the changes in running performance have not been by chance, but is due to the amount of training performed. This may indicate a moderate relationship between improved aerobic capacity and running performance. Improvement in $\dot{V}O_2max$, the fractional utilization of $\dot{V}O_2max$ and running economy is usually expected to be a result of a large running volume performed in a training period[44]. $\dot{V}O_{2max}$ is one of the most important determinants of endurance running[6]. Some researchers claim that endurance training with low intensity has minimal effect in developing $\dot{V}O_2max$[35]. Test results from three of the four runners in this study, however, show that $\dot{V}O_2max$ was 79.2 ± 4.8 ml • kg^{-1} • min^{-1}. The best long-distance runner, who finished 2nd in the European Cross Country Championship, is the one who did not test $\dot{V}O_2max$ in 2008. Although the $\dot{V}O_2max$ may be a limiting factor for the performance in typical endurance events, the fractional utilization of $\dot{V}O_2max$ and running economy may also be of great importance for success[39,45,46]. According to the scientific literature, a moderate correlation is observed between the fractional utilization of $\dot{V}O_2max$ and running performance[47-49]. The trainability of running economy, however, shows conflicting results. Some studies have shown that training volume significantly improved running economy[26,35,50,51], while other studies have shown no improvement[52,53].

TRAINING INTENSITY

The question remains of whether there is an optimal intensity distribution of training which should be recommended for young, talented middle- and long-distance runners. The main finding in the present study was that in the building-up period 78.3 ± 4.7 % of the total volume (km/week) was executed below anaerobic threshold and 19.6 ± 5.4 % at the anaerobic threshold. In the two competition seasons, 11.7 ± 3.3 % and 17.9 ± 5.9 % of the training volume was performed at the anaerobic threshold.

The high volume of interval training close to the anaerobic threshold might have resulted in favourable improvements of aerobic capacity parameters such as: vAT, $\dot{V}O_2max$, fractional utilization of $\dot{V}O_2max$ and running economy. The advantage of anaerobic threshold training is that one can have relatively high training volume on each training workout. This may lead to increased capacity of oxygen transportation and improved running economy. Researchers and expert coaches of top international athletes underline the importance of the close to anaerobic threshold training to develop running economy which is needed to perform on a high level in long distance-running[45]. According to Svedenhag[54], increased vAT may correspond to changes in running economy and $\dot{V}O_2max$.

There is a disagreement in the literature about how workouts below, at or above the anaerobic threshold influence performance in endurance events. According to Helgerud[35], training with high intensity (90-95 % of HR_{max}) results in faster and more effective improvements of the aerobic system than low-intensity training. Other studies, however, have found similar metabolic adaptations in untrained persons, when intensive interval training was compared with traditional endurance training[37,38].

The training data from the present study show that approximately 80 % of the total amount of aerobic endurance training, in the building-up period, was done below the anaerobic threshold and 20 % of the training volume with intensities at the anaerobic threshold. This tendency was also found in other training-studies[19,24,27]. Due to competitions and training in specific race pace, more high-intensity training is done in the competition seasons.

ANAEROBIC THRESHOLD TRAINING VERSUS TRAINING AT SPECIFIC RACE PACE

In the track competition season, the athletes ran from one to three interval sessions at intensities around the anaerobic threshold and one to two sessions at race pace. It is important to point out, however, that the athletes never ran three sessions at race pace and three anaerobic threshold sessions in the same week during the track competition season. A typical distribution reported by the athletes could for instance be two sessions at race pace and two anaerobic threshold sessions, or one session at race pace and two to three anaerobic threshold sessions.

In Table 3, we can see that athlete A in a competition-free week, in the track competition season, ran three anaerobic threshold workouts, classified as Zone 2 sessions (Tuesday p.m., Saturday a.m. and Saturday p.m.). Progressive running (Tuesday p.m.) means that the athlete starts to run the first 6 km with HR 70-75 % of $HR_{max,}$ followed by 5 km with HR 75-82 % of $HR_{max,}$ and then 5 km with HR 82-92% of HR_{max}. One session (Thursday p.m.) is carried out in 5000m/10000m race pace, Zone 3.

In Table 4, we see a week containing an important competition for athlete D. In addition to the 1500m competition (Tuesday p.m.), he includes a session in 800m race pace, Zone 4 (Thursday p.m.) and one session at anaerobic threshold pace, Zone 2 (Sunday p.m.).

It is important to point out that in the track competition season the weekly training differs more between runners and from week to week, than in the building-up period. For each individual runner, the weekly training program differs according to races, racing distance and importance of the race. This is shown in Tables 3 and 4. Runner A is a long-distance runner who, at an age of 17, ran 14:02.95 on 5000m in 2008. Runner D, also 17 years old in 2008, is a middle-distance runner who ran 3:50.63 on 1500m.

CONCLUSION

Newer studies on moderate- and well-trained endurance athletes have demonstrated increased $\dot{V}O_2max$ in endurance athletes when high-intensity training (90-100 % of HR_{max}) replaced training performed at low- and moderate intensities[29,30,32,34,35]. Many coaches and athletes in different endurance events have recently incorporated this training strategy in their workouts in order to optimize performance.

The main findings in this study, however, was that a relatively high training volume with low intensity (62-82% of HR_{max}) combined with training close to the anaerobic threshold (82-92% of HR_{max}) was beneficial for the development of $\dot{V}O_2max$ and running performance in track and cross country competitions in elite junior middle- and long-distance runners.

Among Norwegian national coaches and endurance athletes, there is a consensus that a high weekly training volume based on continuous running combined with two, three or four workouts at anaerobic threshold pace in the building-up period, and more emphasis on training workouts at actual race pace in the competition seasons, is a success factor.

Future research should focus on the effect of endurance training comparing the amount of intensity distribution of training below, at and above the anaerobic threshold zone for longer periods in well-trained athletes. This could increase our knowledge of the significance of high training volume and intensity distribution in order to develop aerobic and anaerobic capacity in elite middle- and long-distance runners.

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