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Distribution of Training Volume and Intensity of Elite Male and Female Track and Marathon Runners

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ABSTRACT

The aim of this study was to compare training volume and the distribution of training intensity of six of the best long-distance runners in Norway from the last decade.

Three international-level long-distance runners (two males and one female) and three marathon runners (one male and two females) were included. The runners' training diaries for one of the seasons they competed in an international championship were analysed. The reported running volume (km/week) was used to estimate the distribution of training at the prescribed intensity zones in representative weeks in the preparation period and in the competition season.

During the preparation period (November - February) the marathon runners ran an average of 186.6 ± 25.7 km/week and the track runners 161 ± 11 km/week. For all runners, 80 ± 5% of the weekly training distance (km/week) in this period was continuous running with a heart rate (HR) between 65-82% of maximum. The remaining 20% of total training volume (km/week) was performed at intensities near and above the anaerobic threshold (82-92% of HRmax). This was done in three to five weekly interval sessions or continuous running sessions. All athletes ran 11 - 13 sessions per week. The training volume (km/week) in the pre-competition period and the competition season did not differ much from the volume in the preparation period. The track runners increased the amount of high-intensity training at specific race pace in the pre-competition period (March and April), and in the track competition season (May - September).

Key words: Aerobic Capacity, Anerobic Threshold, Excercise Intensity, Interval Training, Long-Distance Running, Periodisation, Training Diary

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INTRODUCTION

The research literature indicates that the strongest predictors of long-distance running performance are maximal oxygen uptake ($\dot{V}O_2max$)[1], running economy (RE)[2,3] and the velocity at anaerobic threshold (vAT)[4,5]. Research has also shown that there is a marked variability between individuals in their physiological response to a standardized training program, indicating different trainability[6,7].

How to train to improve aerobic capacity ($\dot{V}O_2max$) in well-trained long distance runners, is a debated topic among coaches and researchers throughout the world[8-11]. Many attempts have been made to develop a long distance training model that optimizes physiological adaptations and enhances performance[12-15]. A consensus on how the exercise variables training volume (km/week), training frequency (training units/week) and distribution of training intensity measured in percent of maximum heart rate (% of HR_{max}) should interact in the different meso-cycles when developing an optimal training program remains elusive[11].

A review of the research literature shows that many of the most successful long distance runners do workloads of 150-260 km per week during a normal season[12-17]. The training of international marathon runners is based on one of two basic models: model 1) workloads with an average of 200-260 km/week based on high training volume at low intensity (< 60-75% of $\dot{V}O_2max$); and model 2) workloads with an average of 150-200 km/week with a greater proportion of the running at higher intensities (80-87% of $\dot{V}O_2max$). Both models have been shown to be beneficial for performance at a high international level[13].

The significance of training intensity in endurance events has been studied extensively over the years, but it has not yet been identified which combination of training at different intensity levels is most advantageous for the development of aerobic capacity and performance in the yearly meso-cycles. Recently, several training intervention studies have examined the effect of high intensity training[18-20]. In these studies, moderately-trained athletes performed high intensity interval training (85-95% of $\dot{V}O_2max$), and results suggest that a high intensity training model also enhances performance in highly-trained endurance athletes. Some studies have also shown that continuous running at moderate intensity (75-85% of $\dot{V}O_2max$) with a duration of 30-50 minutes can stimulate an increase in aerobic capacity ($\dot{V}O_2max$) in moderately-trained endurance athletes[10,19].

Other studies have shown significant improvements in $\dot{V}O_2max$ and running speed at anaerobic threshold (vAT) in elite endurance athletes using the anaerobic threshold training model (80-87% of $\dot{V}O_2max$/ 82-92% of HR_{max})[21-23]. Indeed, the runners with greatest success, the Kenyan runners, do a lot of training at this intensity[24,25]. Experienced coaches and researchers emphasize that training at vAT is the most likely to develop aerobic capacity and specific endurance for long-distance runners[22,26,27].

Newer studies conducted with well-trained long-distance runners, however, indicate a stronger correlation between performance and high-training volume at lower intensity (< 60-75% of $\dot{V}O_2max$), than lower training volume at moderate and high intensities[12,28,29].

In a review article, Berg[30]discusses several limitations in running research, and identifies several areas where research is needed to enhance our knowledge of running performance, including a further examination of training methods. A review of literature shows that the development of training methods has traditionally been based on short-term studies that used untrained or moderately-trained individuals, coupled with anecdotal evidence from experienced coaches and successful athletes[11]. It remains unclear how physical adaptations that occur in untrained subjects and highly-trained subjects differ [31]. Because of the gap in our knowledge of how training volume (km/week) and intensity distribution (% of HR_{max}) should interact in a training program intended to develop aerobic capacity ($\dot{V}O_2max$)[32] and

performance in long-distance runners, more longitudinal studies are needed[22]. This accounts for more systematised data from field conditions and practical training experience rather than laboratory testing[30] and should also include the periodization of training loads in the different meso-cycles of a year to optimize performance[32].

The purpose of this study was to present training data from a descriptive study of six Norwegian runners who have competed or are currently competing at the top European level. The examination process is based on systematic analysis of the athletes' written training diaries for one of the seasons they competed in an international championship. The distribution of training volume (km/week) at different intensities (% of HR_{max}) was determined according to the intensity zones and duration of training recommended by the Norwegian Olympic Training Centre[33]. According to Bompa[53] training volume and the distribution of training at prescribed intensity zones differ during the main meso-cycles of a training year.

METHODS

SUBJECTS

Six of the best Norwegian long-distance runners during the last decade, including three track runners (A, B, C) and three marathon runners (D, E, F) volunteered to take part in the study. They have all participated in international meets and races, and the track runners have competed in finals in international championships. Their personal records in different running events are listed in Table 1.

Table 1. The Best Results at Different Distances for the Runners in the Study

	3000m	**3000m Steeple-chase**	**5000m**	**10000m**	**Half-Marathon**	**Marathon**
A: Male	7:40.60		13:06.39			
B: Male	7:57.60	8:16.75	13:54.51			
C: Female	8:40.22		14:48.53	30:32.36		
D: Male			14:02.70	28:38.89	1:03:22	2:14:00
E: Female			15:46.02	32:28.16	1:09:28	2:27:06
F: Female	8:58.75		16:00.51	32:31.45	1:10:19	2:29:12

All participants gave their written voluntary consent prior to participating in the study.

PROCEDURES

Each runner was asked to send in his/her training diary for one season in which they had competed in the Olympic Games, World Championships or European Championships. Five of the runners complied with this request, while one track runner sent representative weeks for the preparation period (November - February) and the competition season (May - September).

Calculations on the training reported in the diaries was used to estimate: a) average number of training sessions during the preparation period (November - February), the pre-competition period (March and April) and the competition season (May - September)[22,34,35]; b) average training volume (km/week); c) distribution of training at the prescribed intensities (% of HR_{max}); and d) number of weekly sprints/strides and strength training workouts.

INTENSITY ZONES AND TRAINING VOLUME

The training registration protocol was based on the distribution of training into specific intensity zones recommended by the Norwegian Olympic Training Centre[33]. Table 2 consists of seven standardized intensity zones defined in terms of % of maximum heart rate (% of HR_{max}), blood lactate concentration, racing speed and duration of the training sessions. Training performed in the prescribed intensity zones suggests a degree of specific physiological adaptation, but the boundaries between the zones do not clearly underlie exact physiological parameters.

Table 2. Standardized Intensity Zones (HR as % of HR_{max}), Running Pace and Type of Training. Blood Lactate Concentration, and Physiological Adaptation in the Prescribed Intensity Zones

Zone	Running pace/Type of training	Lactate (mmol/L) LT-1710	HR as % of HR_{max}	Physiological adaptation
1	Easy and moderate running pace	0.7-2.0	62-82	Running economy
2	Marathon pace (mainly relative hard continuous running or intervals from 5000m to 2000m)	2.0-3.0	82-87	Anaerobic threshold pace
3	Half marathon pace (hard continuous training and longer intervals from 1000m - 3000m)	3.0-4.5	87-92	Anaerobic threshold pace
4	10000m pace (mainly intervals from 1000m- 2000m)	4.5-7.0	92-95	$\dot{V}O_2$max / aerobic capacity
5	5000m -3000 pace (mainly intervals from 400m to 1000m in 5000m pace and from 600m to 400m in 3000m pace)	7.0-11.0	95-100	$\dot{V}O_2$max: aerobic/ anaerobic mix zone
6	1500m-800m pace (mainly distances from 200m to 400m)	>11	100	Anaerobic capacity
7	Sprint / strides			Speed

Frequency of training (units/week) and average duration of training sessions (km/week) were registered and summarized for all six runners (A—F) in the different meso-cycles of the selected macro-cycle (Table 3a). The reported training loads (km/week) were also classified according to the prescribed intensity zones (table 3b and 3c) and listed for the preparation period, the pre-competition period and the competition season, representing an average of all training done by all six track and marathon runners. In addition, an average training week in the preparation period and in the competition season is presented for all runners (n = 6) (Tables 4a – f, and 5a – f), respectively.

INSTRUMENTS

Two of the track runners and one of the marathon runners used heart rate monitors in most of their training. These runners also measured training intensity during interval sessions by sampling lactate using Lactate Pro LT – 1710™ (ArkRay Inc, Koyota, Japan). The other two marathon runners occasionally used heart rate monitors, and their running speed and heart rate were calibrated against lactate measurements at national training camps. Training performed at intensities around 90% of HR_{max} (85% of $\dot{V}O_{2max}$) is referred to as the anaerobic threshold intensity. Measurements of Norwegian elite endurance athletes' individual anaerobic threshold show that the HR at vAT is in this area[33]. Runners and coaches reported lactate measured at this intensity, using Lactate Pro LT – 1710™ (ArkRay

Inc, Koyota, Japan), to be between 3.0 and 4.5 mmol/L. The identification of HR at anaerobic threshold made it possible to quantify the amount of training in this intensity zone (zone 3). The third track runner did not use a heart rate monitor or Lactate Pro LT – 1710^{TM} while training.

STATISTICAL ANALYSIS

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

RESULTS

FREQUENCY OF TRAINING

During the preparation period, the athletes reported an average of 13 ± 1 training sessions per week. During the pre-competition period and competition season the average number of training sessions was 12 ± 2 and 12 ± 2, respectively.

COMPETITIONS

The track and marathon runners took part in 11 ± 2 and 8 ± 3 competitions, respectively, during the season.

TRAINING VOLUME

The average kilometer ran per week in different periods of the year for all runners are listed in Table 3a. The track runners (B, C) reported an average of 161 ± 11 and 167 ± 3 km/week during the preparation period and the pre-competition period. Runner A reported two training weeks from the preparation period, and one week from the competition season of: 175, 210 and 143 km/week, respectively. In a "typical" week in the competition season, including an important competition, the average running volume for the track runners A, B and C was 148.2 ± 16.1 km.

Average training volume for the marathon runners D, E, F was 186.6 ± 25.7 km/week in the preparation period, and 186.6 ± 18.9 km/week in the pre-competition period. The average documented training volume for the marathon runners in the competition season was 173.3 ± 5.9 km/week.

INTENSITY DISTRIBUTION

Preparation Period

Table 3b shows the average total running distance (km/week) and the average running distance (km/week) in different intensity zones in the preparation period, the pre-competition period and in the competition season for the track runners. Of the track runners' (B and C) weekly running volume (km/week) during the preparation period, 76.4 ± 1.6% (123 ± 11 km) was continuous running with a heart rate between 65-82% of HR_{max} (zone 1). The percent of training performed just below the anaerobic threshold with a heart rate between 82 and 87% of HR_{max} (marathon pace - zone 2), was 12.5 ± 1.3% (20.1 ± 4.2 km) for the track runners. The training reported in zone 2 consisted of mainly interval sessions, but the training did include some hard continuous runs. The track runners performed from two to four sessions per week in zone 2, with a variation from week to week according to the planned training structure. The percent of running volume in zone 3 (half marathon pace) was 7.1 ± 0.8% (11.5 ± 5.1 km) for the track runners (87-92% of HR_{max}). This was mainly long interval training.

During this period, 2.7 ± 1.5% (4.4 ± 3.6 km) of the training for the track runners was reported to be training in 3000m – 5000m pace (zone 5). 1.3 ± 0.2% (2 ± 1.3 km) of the

training volume was reported to be strides or speed training (zone 7).

Table 3c shows the average total running distance (km/week) and the average running distance in different intensity zones, in the preparation period, the pre-competition period and in reported representative weeks in the competition season for the marathon runners. Of the marathon runners' (D, E, F) the weekly training distance (km/week) during the preparation period, 83.6 ± 4.0% (156.2 ± 21 km) was continuous running with a heart rate between 65-82% of HR_{max} (zone 1). The percent of training volume performed at marathon pace was 12.7 ± 3.5 % (23.7 ± 8.2 km), with a heart rate between 82 and 87% of HR_{max} (zone 2). The athletes performed from two to four sessions per week in zone 2, with a variation from week to week according to the planned training structure. The marathon runners did not report any training at half marathon pace (zone 3). However, during this period, 2.5 ± 1.2% (4.7 ± 2.4 km) of the training volume for the marathon runners was training at 10000m pace (zone 4). 1.2 ± 0.7% (2 ± 0.9 km) of the training volume was reported to be strides or speed training (zone 7).

Pre-Competition Period

The intensity distribution in this period was very similar to the distribution in the preparation period, except that the track runners performed 2.9 ± 0.8% (4.8 ± 0.9 km) of their training in zone 6 (mainly track running at 1500m pace).

Competition Season

During the competition season the track runners (A, B, C) performed 80.8 ± 2.1% (119.4 ± 9.8 km) of the training volume in zone 1, 6.9 ± 1.1% (10.2 ± 4.2 km) in zone 2, and 6.2 ± 2.6 (9.2 ± 5.1 km) in zone 3. Compared with the pre-competition period more training was done in 10,000m pace (0.3 ±0.5 % = 0.5 ± 0.9 km) and 3000m-5000m pace (4.0 ± 2.0% = 6.0 ± 2.0 km). This is due to competitions and training at specific 3000m or 5000m pace.
Compared to the preparation and the pre-competition periods, the marathon runners increased the amount of training in zone 2 to and 3. The volume in zone 2 is nearly the same as in the two previous periods, but now 4.1 ± 2.9% (7.1 ± 4.8 km) was carried out in zone 3.

STRIDES AND STRENGTH TRAINING

Strides, often carried out before interval sessions, and occasionally after continuous running sessions, are categorized as zone 7 training. The total amount, intensity and length of strides are not always reported in the diaries, resulting in some uncertainty regarding the amount of training in zone 7. All runners reported some kind of general strength training. This training was not specified in detail in the training diaries, and is not listed in Tables 3b and 3c.

WEEKLY TRAINING PROGRAMS IN THE PREPARATION PERIOD

Table 4a shows track runner A's training week in the preparation period (week 9). The listed training program was performed at 2000-2400m above sea level in Eldoret, Kenya, and the total running volume was 210 km. Runner A performed 12 training sessions during this week of which eight sessions were continuous running in zone 1. The four other sessions were: One session in zone 2 (Wednesday p.m.), one session in zone 3 (7 x 2000m with one minute recovery), one session in zone 4 (14 x 1000m, recovery = 45 sec) and one track running session (10 x 200m) where every second 200m was performed in 800m pace (zone 5) and 5000m pace (zone 6) with a recovery period of 2:00 – 2:30 min between repetitions and a lactate production just below 10.5 mmol/L.

The training week in the preparation period (week 47) for track runner B was performed

at 2100m above sea level in South Africa. The presented program (Table 4b) indicates a total running volume of 165.5 km. Runner B performed 12 training sessions during this week of which seven sessions were continuous running in zone 1, two and a half sessions were training in zone 2 (Tuesday a.m., Thursday p.m. and the first five 1000m of the session on Tuesday p.m.) and one and a half session were carried out in zone 3 (6 x 6 min Thursday a.m., and the last seven 1000m of the session on Tuesday p.m.). One track running session (Saturday p.m.) was carried out at 5000m pace (zone 5).

A representative training week in the preparation period (week 47) for female track runner C at sea level in Oslo is shown in Table 4c. The presented program indicates a total running volume of 172 km performed in eleven training sessions of which nine sessions were continuous running in zone 1, one session continuous running including 45 min moderate running in zone 2 and one anaerobic threshold training sessions in zone 3 (8 x 1500m with a recovery of 45 sec).

Table 4d shows a representative training week for male marathon runner D in the preparation period (week 49), 2100m above sea level in Flagstaff, USA. The program indicates a total running volume of 177 km performed in 12 training sessions of which ten sessions were continuous running in zone 1 and two training sessions in zone 2. The training week seems relatively hard and monotonous, but it is worth noting that one of the continuous running sessions was done with a moderate intensity (Friday p.m.). On Sunday a.m. runner D performed 20 x 1000m in marathon pace with a recovery period of 1min.

In a week (Table 4e) in the preparation period (week 4) female marathon runner E performed a total running volume of 232 km in 14 training sessions of which eleven sessions were easy continuous running in zone 1, and three threshold training sessions in zone 2.

Table 4f shows a representative week in the preparation period for female marathon runner F. The training program indicates a total running volume of 215 km performed in 12 training sessions of which nine sessions were continuous running in zone 1 and two sessions close to marathon pace in zone 2 (Tuesday a.m.; 16 x 1000m in a pace of 3:25 min/km with a recovery of 30sec., and Saturday a.m.; 4 x 5 km at a pace of 3:20 – 3:40 min per km).

WEEKLY TRAINING PROGRAMS IN THE COMPETITION SEASON

A representative training week in the competition season (week 23) for male track runner A is shown in Table 5a. The total running volume was 143 km in 12 training sessions of which eight sessions were continuous running in zone 1, one session in zone 3 (Wednesday p.m.; 6 x 2000m with a pace of 2:53 min/km), one session was performed in zone 5 (4x1000m in 5000m pace – average time 2:32min/km) and one track running competition (5000m – 13:09.19) in zone 5. On Sunday p.m., the runner performed an ergometer bike session in simulating high altitude at 3000m.

Table 5b shows a training week in the competition season (week 22) for track runner B. The presented program indicates a total running volume of 131.5 km. Runner B performed 12 training sessions during this week of which nine sessions were continuous running in zone 1, one session in zone 2 (Thursday p.m.) and one anaerobic threshold training sessions in zone 3 (Thuesday p.m.) and one competition (zone 5).

In the competition season (week 30 - Table 5c) female track runner C ran a total volume of 172 km performed in 12 training sessions of which nine sessions were easy continuous running in zone 1 and two training sessions in zone 2, and a 3000m competition (zone 5) on Friday p.m. (8:41.34).

Table 5d shows a representative training week in the competition season (week 30) for male marathon runner D. The presented program indicates a total running volume of 178 km

performed in 13 training sessions of which 11 sessions were continuous running in zone 1, one session in zone 3 (5 x 2000m in half-marathon pace, recovery = 2min) and one session at 5000m and 1500m pace (6 x 800m in 2:11-2:12 min (zone 5) + 12 x 300m in 45-49 sec (zone 6)).

A training week in the competition season (week 32) for female marathon runner E is illustrated in Table 5e. The listed program indicates a total running volume of 165 km performed in 11 training sessions of which nine sessions were easy continuous running in zone 1, one sessions in zone 2 (Friday a.m.; 32 x 1000m in a average pace of 3:25 min/km, recovery = 1min) and one session at 10000m pace (zone 4) (25 x 400m, recovery = 30 sec).

Table 5f shows a representative training week in the competition season (week 28) for female marathon runner E. The presented program indicates a total running volume of 177.5 km performed in 11 training sessions of which nine sessions were continuous running in zone 1 and two sessions in zone 2 (Tuesday a.m.; 35 km continuous running with a varied speed between 4:00 and 3:20min/km for each 10 km and 5 km, respectively and 20 km continuous running on Thursday p.m.).

Table 3a. Average Running Volume (km/week) in the Different Meso-Cycles of the Year for Runner B, C, D, E and F
The listed kilometer for runner A* is an average of two reported training weeks in the preparation period, and one week in the competition season

	A	B	C	D	E	F
Preparation period	192.5*	150	172	154	216.8	189
Pre-competition period		131.8	173	149	197.2	177.5
Competition season	143*	120	160	148.3	181.3	148

Table 3b. Average Total Running Distance (km/week), and Average Running Distance in Different Intensity Zones (km/week), in the Preparation Period, the Pre-Competition Period and in Reported Representative Weeks in the Competition Season for the Track Runners

	Preparation period (November-February) n=2	Pre-competition period (March and April) n = 2	Competition season (May-August) n =3
Total km /week	161 ± 11.0 km	167 ± 3.0 km	148.2 ± 16.1 km
Zone 1: Easy and moderate continuous running	123 ± 11.0 km (76.4 ± 1.6 %)	131.9 ± 5.7 km (79 ± 2.0 %)	119.4 ± 9.8 km (80.8 ± 2.1 %)
Zone 2: Marathon pace	20.1 ± 4.2 km (12.5 ± 1.3 %)	11 ± 3.2 km (6.5 ± 1.4 %)	10.2 ± 4.2 km (6.9 ± 1.1 %)
Zone 3: Half marathon pace	11.5 ± 5.1 km (7.1 ± 0.8 %)	13.3 ± 3.3 km (8.0 ± 0.6 %)	9.2 ± 5.1 km (6.2 ± 2.6 %)
Zone 4: 10000m pace			0.5 ± 0.9 (0.3 ± 0.5 %)
Zone 5: 3000m- 5000m pace	4.4 ± 3.6 km (2.7 ± 1.5 %)	2.8 ± 2.8 km (1.7 ± 1.7 %)	6.0 ± 2.0 km (4.0 ± 2.0 %)
Zone 6: 800m -1500m pace		4.8 ± 0.9 km (2.9 ± 0. 8 %)	0.9 ± 0.6 km (0.9 ± 0.7 %)
Zone 7: Sprint / strides	2 ± 1.3 km (1.3 ± 0.2 %)	3.2 ± 0.9 km (1.8 ± 0.2 %)	2.0 ± 0,0 km (1.3 ± 0.1 %)

Table 3c. Average Total Running Distance (km/week), and Average Running Distance in Different Intensity Zones (km/week), in the Preparation Period, the Pre-Competition Period and in Reported Representative Weeks in the Competition Season for the Marathon Runners

	Preparation period (November-February)	**Pre-competition period (March and April)**	**Competition season (May-August)**
Total km/week	186.6 ± 25.7 km	187.6 ± 18.9 km	173.3 ± 5.9 km
Zone 1: Easy and moderate continuous running	156.2 ± 21.0 km (83.6 ± 4.0 %)	158.2 ± 9.2 km (84.7 ± 4.2 %)	138.4 ± 15.2 km (79.9 ± 6.5 %)
Zone 2: Marathon pace	23.7 ± 8.2 km (12.7 ± 3.5 %)	22.2 ± 8.8 km (11.5 ± 3.6 %)	22.6 ± 12.0 km (13.1 ± 5.6 %)
Zone 3: Half marathon pace			7.1 ± 4.8 km (4.1 ± 1.9 %)
Zone 4: 10000m pace	4.7 ± 2.4 km (2.5 ± 1.2 %)	4.4 ± 2.5 km (2.3 ± 1.3 %)	
Zone 5: 3000m-5000m pace			1.6 ± 2.6 km (1.0 ±1.3 %)
Zone 6: 800m-1500m pace		0.5 ± 0.2 km (0.3 ± 0.3 %)	1,3 ± 1.8 km (0.7 ± 1.0%)
Zone 7: sprint / strides	2 ± 0.9 km (1.2 ± 0.7 %)	2.3 ± 0.5 km (1.2 ± 0.3 %)	2.3 ± 5.0 km (1.3 ± 0.3 %)

Table 4a. A Training Week in the Preparation Period for Runner A (Eldoret, Kenya 2000 - 2400m Above Sea Level)

Week 9	**a.m.**	**p.m.**
Monday	11 km continuous running	14x1000m La: 5-7mmol/L Pace: 2:50-2:55, recovery 1 min
Tuesday	17 km continuous running	12 km continuous running
Wednesday	10 km continuous running + 5x100m jumping (sprunglauf) 6x100 elastic leg jumps	11000m+8000m+ 4500m +3000m+1500m (recovery 2-1 min). La: 2-3 mmol/L (zone 2)
Thursday	16 km continuous running	14 km continuous running
Friday		7x2000m threshold pace, recovery 1 min
Saturday	20x60m sprint (the last 10 with 2.5kg weight loaded hanging behind) + 6x100 elastic leg jumps	10x200m, track running. Every second in 800m- and 5000m pace.Average: 26.0sec and 32.5sec. Recovery 2:00-2:30 min. Lactate< 10,5mmol/L
Sunday		20 km continuous running
12 sessions = 210 km		

Table 4b. A Training Week in the Preparation Period for Runner B (South Africa, 2100m Above Sea Level)

Week 47	a.m.	p.m.
Monday	13 km (60min) continuous running	10 km (45min) continuous running
Tuesday	Warm up 10 min. +7,5km continuous threshold running. La< 3.0 mmol/L (3:24 - 3:27min/ km) + 15 min jog	Warm up 15min +12x1000m recovery =1min (average: 3:13min) La: 2.7-3.6 mmol/L + 15min jog
Wednesday	62 min = 13 km	45 min = 10 km
Thursday	Warm up 15 min + 6x6min (3:17-3:25min/km), recovery 1 min. La: 2.9-3.6 mmol/L + 15min jog	Warm up 10 min +7.5km continuous threshold running (3:24min/km) La: 1.9mmol/L + 10 min jog
Friday	21.5 km continuous running (1:37)	
Saturday	Warm up 10 min +7,5km continuous threshold running (3:20 min/ km) La: 4.2 mmol/L + 10 min	Warm up 13 min + 15x400m (1800m above sea level): average time 67.9 sec., La: 9.7 – 10.7 mmol/L, recovery =1min + 15 min jog
Sunday	22 km continuous running (1:40)	
12 sessions = 165.5 km		

Table 4c. A Training Week in the Preparation Period for Runner C (Oslo, Sea Level)

Week 4	a.m.	p.m.
Monday	11.5 km continuous running (46 min = 4 min/km)	Warm up 4 km + strides + 8x1500m, (recovery =45sec jog) + jog 4 km
Tuesday	16 km continuous running (70 min)	
Wednesday	11.5 km continuous running (46 min)	19 km continuous running (80 min) 4:12 min/ km
Thursday	17.5 km continuous running (included 45 min moderate/ hard= 3:40-3:30 min/km) (67 min)	
Friday	11.5 km continuous running (46 min)	15 km continuous running (64 min)
Saturday	11 km continuous running (44 min)	14 km continuous running (60 min)
Sunday	28 km continuous running (120 min)	
11 sessions = 172 km.		

Table 4d. A Training Week in the Preparation Period for Runner D (Flagstaff, U.S.A., 2100m Above Sea Level)

Week 49	a.m.	p.m.
Monday	8 km continuous running + 6x100m strides	13.5 km continuous running + general strength training
Tuesday	9.5 km continuous running	14 km continuous running
Wednesday	9.5 km continuous running	17 km min continuous running including 5,4,3,2,1 min marathon pace with 1 min jog recovery.
Thursday	7.5 km continuous running	20 km continuous running + general strength training
Friday	9 km continuous running + drills	12 km moderate + 6 x100m sprint
Saturday	25 km easy continuous running	
Sunday	Warm up 3.5 km + 20x1000m (marathon pace) (zone 2), recovery = 1 min + 3.5km jog	
12 sessions = 177 km		

Table 4e. A Training Week in the Preparation Period for Runner E (Norway, Sea Level)

Week 4	**a.m.**	**p.m.**
Monday	40.5 km continuous running (4:30min/km)	11km continuous running (50 min) + strides
Tuesday	11.5 km (52min) continuous running	22 km continuous running + strides
Wednesday	13.5 km continuous running (59min) + strides	4.5 km warm up+ strides + 4 x 15min (3:30min/km) + 5.5 km jog
Thursday	14 km continuous running (4:30-4:20min/km)	56 min continuous running + 4 x 100m
Friday	14 km continuous running + 3 x100m	21 min warm up+4x100m strides +short intervals: 40 x 1 min (recovery =30sec)+20min jog
Saturday	27 km continuous running (4:30min/km)	50 min + 4 x 100m
Sunday	14 kmcontinuous running + 4 x100m strides	Warm up 4 km + 4 x100m strides + 8 x 5min l (3:25min/km, recovery=1min)+ 4 km jog
14 sessions = 232 km.		

Table 4f. A Training Week in the Preparation Period for Runner F (Norway, Sea Level)

Week 7	**a.m.**	**p.m.**
Monday	13 km continuous running (65min)	16 km continuous running (70 min)
Tuesday	7 km continuous running (4:16 per km)+16x1000m (3:25), recovery = 30sec + 5km continuous running	19 km continuous running (90 min)
Wednesday	16 km continuous running	14 km easy continuous running (70 min)
Thursday	15 km continuous running (4:00min/km)	26 km continuous running (120 min)
Friday	15 km continuous running (65min)	13 km continuous running (60 min)
Saturday	Warm up: 3.5 km + 20 km progressive treadmill running: 5 km(3:40min/km) + 5 km (3:25min/km) +5 km (3:40min/km) +5km (3:20min/km) + 3.5km jog	
Sunday	13 km continuous running	
12 sessions = 215 km		

Table 5a. A Representative Training Week in the Competition Season for Runner A

Week 23	**a.m.**	**p.m.**
Monday	7 km continuous running	4x1000m. Times: 2:32.2-2:32.4-2:32.2-2:32.1 (recovery = 3min) + 5x300m Times: 42-43 sec (recovery = 1min) + 3x3 deep, fast knee bend 40 kg, 1 x 3 horizontal jumps (light weights) + 10 km jog
Tuesday	13 km continuous running + 5x100 jumps (legs)	
Wednesday	8 km continuous running	Warm up 15 min + 6x2000m (La: 2.5-3.0 mmol/L) 2:53 per km (recovery = 1min) + jog 10-15 min
Thursday	10 km continuous running	17 km continuous running
Friday	3 km continuous running	5000m, Bislett Games 13:09.19 (2:37-2:38-2:41-2:44-2:28)
Saturday	13 km continuous running + massage	
Sunday	10 km continuous running	Ergometer bike: 35 min moderate frequency (3000m; stimulated altitude) La: 2.5-3.0 mmol/L.
Total: 143 km		

Table 5b. A Representative Training Week in the Competition Season for Runner B

Week 22	a.m.	p.m.
Monday	14.5 km continuous running (64 min)	10 km continuous running (41min)
Tuesday	10 km continuous running (44 min)	Warm up 15 min +12x1000m, recovery = 1min (2:56 - 3:05/km). La: 2.9-4.0 mmol/L (zone 4)+ jog 15 min
Wednesday	14,5 km continuous running (61 min)	
Thursday	10 km continuous running (44 min)	Warm up 15 min + strides + 3 x 6min threshold running, recovery = 1min. La: 2.7 mmol/L (zone 3)+ 15 min jog
Friday	6 km continuous running (32 min)	Travel to Belgia
Saturday	5 km easy jog	Neerpelt, competition: 3000m steeplechase: 8:24.80. (Warm up 10min jog + 5min threshold pace + strides. After the race: 20min jog).
Sunday	11 km continuous running (50 min)	10 km continuous running (43 min)
12 sessions = 131.5 km		

Table 5c. A Representative Training Week in the Competition Season for Runner C

Week 30	a.m.	p.m.
Monday	11 km continuous running	Warm up 2.5km + 50min moderate running (3:30 min/km) + 5x100m strides in spike shoes
Tuesday	11 km continuous running	Warm up 3 km + 30min moderate running (3:30 min/km) + 6x200m on track (32-30 sec)
Wednesday	10 km continuous running	10 km continuous running + 6x100m strides in spike shoes
Thursday	7 km continuous running	8 km continuous running + 6x100m strides in spike shoes
Friday	5 km continuous running + strides	Bislett Games 3000m 8.41.34
Saturday	8 km continuous running (very easy)	20 km continuous running
Sunday	14 km continuous running	15 km continuous running + 6x100m strides
14 sessions = 167 km		

Table 5d. A Representative Training Week in the Competition Season for Runner D (Norway, 1850m Above Sea Level)

Week 30	a.m.	p.m.
Monday	9 km continuous running	15.5 km continuous running
Tuesday	9 km continuous running	Warm up 15 min +2x3x800m (2.11-2.12) recovery = 200m jog, 2 min between sets. + 8x300m (49-47sec) + 5x300m (47-45 sec) (recovery = 1 min) + 15 min jog
Wednesday	10 km continuous running	15.5 km continuous running (4:00-3:50 min/km)
Thursday	28 km continuous running(150min)	
Friday	10 km continuous running	14 km continuous running + 6 x 100m strides
Saturday	10 km continuous running	5x2000m, recovery = 2 min
Sunday	15 km continuous running (4:00min/km)	8.5 km continuous running (3:50 min/km)
13 sessions= 178 km.		

Table 5e. A Representative Training Week in the Competition Season for Runner E

Week 32	a.m.	p.m.
Monday	10 km continuous running (4:20 min/km)	15 km continuous running (4:20 min/km)
Tuesday	10 km continuous running (4:20 min/km)	Warm up 15 min + short intervals: 25x400m, recovery = 30 sec + jog 15 min
Wednesday	20 km continuous running (4:20 min/km)	
Thursday	10 km continuous running (4:15 min/km)	20 km continuous running (4:20-4:25 min/km)
Friday	Warm up 15 min+ 32 x1000m (average 3:25 min, recovery=1 min) + jog 15 min	
Saturday	10 km continuous running (4:30 min/km)	
Sunday	10 km continuous running (4:20 min/km)	15 km (4:20 min/km)
11 sessions = 165 km		

Table 5f. A Representative Training Week in the Competition Season for Runner F

Week 28	a.m.	p.m.
Monday	14 km continuous running (60 min)	14 km continuous running (60 min)
Tuesday	35 km continuous running, varying speed:10 km (4:00 min/km)+ 5 km (3:45 min/km)+ 10 km (3:30 min/km) + 2 km (4:00 min/km)+ 3 km (3:20 min/km) + 5 km(4:00 min/km)	
Wednesday	10 km continuous running (45 min)	9 km continuous running (40 min)
Thursday	14 km continuous running (60 min)	20 km continuous running (3:40 min/km)
Friday	14 km continuous running (60 min)	14.5 km continuous running (62 min)
Saturday	24 km (including 20 km progressive running) (total = 97 min)	
Sunday	9 km continuous running	
11 sessions= 177.5 km		

DISCUSSION

The training methods used by high-level athletes are not well documented in the literature. The training process naturally gives smaller adjustments in training response to performance at this level, so for well-trained high level athletes, small improvements in performance parameters are expected compared to the expected training response to performance result for untrained athletes[11].

TRAINING VOLUME

The three track and three marathon runners in this study have all represented Norway in international championships, and are considered the most outstanding long distance runners in Norway during the last decade. They ran an average of 13 ± 1 sessions and a mean volume of 161 ± 11 km/week (track runners) and 186.6 ± 25.7 km/week (marathon runners) in the preparation period. In the pre-competition period they ran a mean volume of 167 ± 3

km/week (track runners) and 187.6 ± 18.9 km/week (marathon runners). In the competition season they ran a mean volume of 148.1 ± 16.1 km/week (track runners) and 173.3 ± 5.9 km/week (marathon runners). According to research literature, success in endurance events is associated with high training volume (km/week) at low intensities (62-82 % of HR_{max}) performed in the preparation period, pre-competition period and competition seasons[36,37]. $\dot{V}O_2max$ is one of the most important determinants of performance in endurance running[8]. Although $\dot{V}O_2max$ may be a limiting factor for performance in typical endurance events, running economy and running pace at the anaerobic threshold may also be of great importance for success in long distance running events[32,38]. The trainability of running economy, however, is uncertain. Some studies have shown that training volume significantly improved running economy[19,39-41], while other studies have shown no improvement[7,42].

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 progressively increased training loads over many years. This model emerges from observations of outstanding distance runners over the last five decades [13,16,17,43].

Runner A in this study trained according to a "low volume / high intensity model" until the age of 21 years. He then changed his training model, increased the average training volume from 80 km/week to 160 km/week, including two or three lactate threshold sessions per week. After 14 weeks (January – April) his anaerobic threshold running velocity (vAT) had increased from 16.3 to 19.3 km/hour, with a measured $\dot{V}O_2max$ of 86.7 $ml \cdot kg^{-1} \cdot min^{-1}$. The following season he finished second in the European under-23 Championships in the 5000m and his personal record at this distance improved from 14:45 min to 13:22.58 min. When runner C increased her training volume she experienced the same kind of improvement in performance. Runner F, however, experienced improvement in her running performance when she reduced her training volume from an average of 270 km/week in a year to an average of 200 km/week, including more training at specific marathon pace. This finding is in line with Billat et al.[44], who reported increased $\dot{V}O_2max$ in elite marathon runners as a result of more training at marathon pace.

TRAINING INTENSITY

Is there an optimal training intensity distribution that should be recommended for long distance runners? The main finding in the present study was that, in the preparation period, 76.4 ± 1.6% of the track runners' total volume, and 83.6 ± 4.0% of the marathon runners' total volume (km/week) was performed below marathon pace, while 19.6 ± 1.8% (track runners) and 12.7 ± 3.5% (marathon runners) was performed at marathon or half marathon pace (zone 2 or 3) which is training close to (zone 2) and at the anaerobic threshold (zone 3). In the pre-competition period and the track competition season, the track runners also reduced training volume and percentage of total running volume performed in zone 2 and 3. This was due to increased training at specific race pace (zones 4 and 5).

The marathon runners carried out the same volume of training at marathon pace (zone 2) in the period leading up to the international championship as in the previous periods, the training at half marathon pace, however, increased from 0% in preparation- and pre-competition period, to 4.1 ± 1.9% (7.1 ± 4.8 km) in the competition season..

The high volume of interval training close to anaerobic threshold (zone 2 and 3) might have resulted in favourable improvements in aerobic capacity parameters like vAT, $\dot{V}O_2max$ and running economy. The advantage of anaerobic threshold training is that one can perform a relatively high running volume in each workout. This may lead to increased oxygen

transportation capacity and improved running economy. Researchers and expert coaches of top international athletes underline the importance of training near the anaerobic threshold in developing running economy, which is needed to perform at a high level in long-distance running[38]. According to Svedenhag and Sjödin[45], increased vAT may correspond to changes in running economy and $\dot{V}O_2max$.

Helgerud et al.[19] claim that training at high intensity (90-95% of HR_{max}) results in faster and more effective improvements in aerobic capacity than low intensity training. However, symptoms of overtraining were found among distance runners who performed three high-intensity interval sessions per week over a 4-week span[46]. Other studies have found similar metabolic adaptations in untrained persons, when intensive interval training was compared with traditional endurance training[47,48].

It is important to take into consideration that the track runners ran 31.6 ± 5.1 km/week just below and at threshold pace (close to 90% of HR_{max}; zone 2 and 3) in the preparation period. The female runner ran at 3:25 ± 0:10 min/km pace and the male runners at 3:00 ± 0:10 min/km pace. When doing steady continuous running, the female and male runners ran at paces of 4:00 – 4:20 min/km and 3:50 – 4:00 min/km, respectively. This means that the runners in this study, when running 120 to 170 km/week with a heart rate between 65-85% of HR_{max}, ran much faster per kilometre than did the so-called 'well-trained athletes', when running 4 x 4min close to $\dot{V}O_2max$[19].

PERIODIZATION OF TRAINING

Preparation Period

The training data from the present study show that approximately 80% of the total amount of aerobic endurance training in the preparation period was performed below marathon pace and 20% at intensities near and above the anaerobic threshold (zone 2 and 3). This tendency has also been found in other training studies[15,22,26,49,50].

The presented training weeks in the preparation periods (Tables 4a, b, d) of the male track runners A and B and marathon runner D indicate the necessity of performing 7-9 continuous running sessions in zone 1 with a total running volume of 165.5-210 km per week, and two to three sessions in zone 2 or 3 combined with one session in 5000m or 3000m pace (zone 5) to be successful on an international level. The presented running volume and training intensity distribution is in line with newer studies which show that many of the most successful long-distance runners and international marathon runners do workloads of 170-250 km per week during their preparation meso-cycles. Studies conducted with well-trained long distance runners also indicate a stronger correlation between performance and high training volume at lower intensity (< 60-75% of $\dot{V}O_2max$), than lower training volume at moderate and high intensities[12,28,29]. With reference to the presented training programs, it is important to underline that male track runner A practised high-altitude training regularly in the preparation meso-cycles of the training year. It is worth nothing that he performed 28 km of running in zone 2 in one single session at high-altitude (table 4a). Studies have shown that training just below and at vAT (80-87% of $\dot{V}O_2max$/ 82-92% of HR_{max}) is the most likely to develop aerobic capacity and specific endurance for long distance runners. The documentation of high-altitude training research also shows that training at 2000m above sea-level might give many positive effects on the development of $\dot{V}O_2max$ and performance in endurance events[51].

The presented training week for track runner B seems relatively hard and it is worth noting that the interval track session on Saturday p.m.; 15 x 400m with a recovery period of 1min (average times 67.9 sec), was performed with a lactate production between 9.7-10.7

mmol/L (zone 5). With reference to the presented training program runner B also practised high-altitude training regularly in the preparation meso-cycles of the training year.

The reported training of female track runner C shows that her running performances was developed on a very solid base of continuous running on low (zone 1) and moderate intensity (zone 1-2) in the preparation meso-cycle of the training year. A representative training program in the preparation period (Table 4c) consisted of 9 relatively hard and monotonous continuous running sessions in zone 1, one continuous session in zone 2 and one interval session in zone 3, with a total volume of 172 km per week. Three of the presented continuous running sessions were performed with a moderate intensity of 4:00 min/km (zone 1). The distribution of the running volume and training intensity in the preparation period is in line with the research literature and the documented practice of earlier female world-class runner Ingrid Kristiansen[36].

With reference to the presented training program of female marathon runners E and F, it is important to state that their running performances also were developed on a very strong base of continuous running on low (zone 1) and moderate intensity (zone 1-2) throughout the preparation period of the training year. The training week for the female marathon runners consisted of 12 relatively hard and monotonous continuous running sessions in zone 1 and zone 2 with a total volume of 180-230 km per week. The female marathon runners did one to two weekly sessions at marathon pace with a total running volume up to 20 km in one single session (zone 2). The described training structure of the female marathon runners is in line with a consensus in the research literature and the practice of international marathon runners of today[13].

Competition Period

Due to competitions and training at specific race pace, more high-intensity training is performed in the competition seasons. A common distribution reported by the athletes could for instance be two sessions at race pace and two sessions in zone 2, or one session at race pace and two sessions in zone 3.

Table 5a shows athlete A's workout sessions during a week in the track competition season. The week includes two sessions in zone 2 (Wednesday p.m., and a bike session on Sunday). One session (Monday p.m.) was carried out at 1500m and 3000m race pace. This session is listed as follows: 4 km (4 x 1000m at 3000m pace - average time 2:32 min/km) in zone 5, and 1.5 km (5 x 300m at 1500m pace) in zone 6. The 5000m competition Friday p.m. is listed in zone 5.

For runner A, the competition week seems quite well structured. The total running was 143 km and it is worth noting the training intensity of the specific session preparing for top-performance in the 5000m which was performed three days before the competition (Bislett Games). It is recommended that the last intensive training session should be performed four days before an important competition in aerobic endurance events[52]. From practical experience, however, we know that the periodization of training in the micro-cycle may vary for each individual runner. Runner A has obviously discovered that a hard training session three days before a competition optimized his performance potential. With reference to the presented training program, it is also important to underline that runner A practised an ergometer simultation session at high altitude on Sunday p.m. which he did regularly on different occasions.

The presented training in a competition week for track runner B (Table 5b) seems relatively easy. It consisted of one session in zone 3 (Tuesday p.m.; 12 x 1000m, 2:56 – 3:05 min/km, Lactate 2.9- 4.0 mmol/L) and one session in zone 2 (Thursday p.m.; 3 x 6 min,

Lactate 2.7 mmol/L) four and two days, respectively, before the 3000m steeplechase competition on Saturday p.m. (8:24.80) The periodization structure in his competition week is in line with the research literature and practice of top international track runners[53].

The competition training week for female runner C is quite well balanced (Table 5c). It is worth noting that two of her continuous running sessions (Monday p.m., 50 min and Tuesday p.m., 30min) were performed with a moderate intensity of 3:30 min/km (zone 2) three and four days before the competition, respectively. With reference to the presented training program, it is important to underline that runner C mainly used continuous running on low (zone 1) and moderate intensity (zone 2) on all running sessions in her competition training week. On Tuesday p.m. she ran six additional 200m's at a pace of 30-32sec and on Wednesday and Thursday p.m. she did 6 x 100m strides in spike shoes. She did not run any sessions in specific race pace before the competition on Friday p.m. Her training structure in the competition week seems a little different from the other track runners. However, the strategy might be an attempt to gain an optimal compensation (surplus of energy) to perform on a high level in the 3000m race which was run in 8:41.34. In the periodization research literature, high-intensity training sessions are suggested to be performed seven and four days ahead of an important competition to optimize the athletes' potential performance[36,53] .

The running capacity of runner D was also developed on a regime of continuous running on low (zone 1) and moderate intensity (zone 1-2) combined with an intensive interval session once a week (zones 5 and 6). In the presented competition season week (Table 5d) male marathon runner D did one session in zone 3 (Thursday p.m. – 5 x 2000m in half-marathon pace, recovery = 2 min) and one session in 5000m pace (zone 5). The training week seems relatively easy and it is worth to notice the detailed structure of the mentioned track interval session run in 5000m pace (zone 5) on Tuesday p.m. (6 x 800m in 2:11-2:12 min + 12 x 300m in 45-49 sec) (zone 6).

Table 5e exemplifies a week leading up to an international marathon championship for athlete E. The athlete ran 25 x 400m at half marathon pace on Tuesday p.m. (zone 3), and 32 x 1000m at marathon pace on Friday a.m. (zone 2). An analysis of the presented training program of female marathon runner E shows that the competition running week was performed with a dominance of continuous running on low and moderate intensity in zone 1 and two interval sessions in zones 2 and 3. All her continuous running sessions were performed with an intensity of 4:20 – 4:30 min per km.

The training week seems relatively hard and one should notice the extremely strenuous interval training session performed in marathon pace (zone 2) on Friday a.m. (32 x 1000m in a pace of 3:25 min per 1000m, recovery = 1min). This session was meant to be a specific preparation (super compensation) for the forthcoming marathon race.

With reference to the presented training program of female runner F (Table 5f), it is important to underline that the running competition week was performed with a solid foundation of continuous running on low (zone 1) and moderate intensity (zone 1-2). The competition training week seems relatively hard and monotonous, and it is worth noting that the continuous running sessions on Thursday a.m. were run with a moderate intensity of 3:40 min per km (zone 2). The session which was run on Tuesday a.m. consisted of: 35 km continuous running with a varied speed between 4:00 (zone 1) and 3:20 min/km (zone 3) for each 10 km and 5 km, respectively. The total running volume in the competition week was 177.5 km. This periodization structure is quite typical for marathon runners at an international level[11-17,32].

It is important to point out that, in the competition season, weekly training programs differ more between runners and from week to week than in the preparation period. For each

individual runner, the weekly training program differs according to races, racing distance and importance of the race.

CONCLUSION

Newer studies on moderately- and well-trained endurance athletes have demonstrated increased $\dot{V}O_2max$ when high-intensity interval training (90-100% of HR_{max}) replaced training performed at low and moderate intensities[18,19,44,53,54]. Many coaches and athletes in different endurance disciplines have recently incorporated this training strategy into their practical training workouts in order to optimize performance.

The main finding in this study, however, was that a relatively high training volume at low intensity (62-82% of HR_{max}) combined with training just below and at the anaerobic threshold (82-92% of HR_{max}) was beneficial for the development of running performance in six Norwegian male and female track and marathon runners competing at top European level.

There is a consensus among Norwegian national coaches and endurance athletes that a high weekly training volume based on continuous running combined with two, three or four workouts just below and at anaerobic threshold pace in the preparation period, and stronger emphasis on training workouts at actual race pace in the competition seasons, is a factor for success. This is in line with the conclusions in a review article by Midgley et al.[32]

Future research should compare the performance effects of different training intensity distributions (below, at, and above the anaerobic threshold) for longer periods. Increased knowledge of the significance of training volume and intensity distribution from a longitudinal perspective would help coaches and scientists to design training programs that improve aerobic and anaerobic capacity in elite long distance runners.

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