A Case Study of the Training of Nine Times New York Marathon Winner Grete Waitz

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ABSTRACT

The purpose of the present study is to give a description of the exceptional running career of Grete Waitz (GW) and give special attention to the distribution of training volume and training intensity in two of her most successful years as an international long-distance and marathon runner. Training data are based on an analysis of GW's training diaries from her early start as a track and field athlete to her best performance years as a long-distance track runner and marathon runner. The main finding in this study was that GW's total running volume, in her best seasons, varied between 119-132 km $\cdot$ week^{-1} in the different meso-cycles of the training year. Her weekly training volume is far below the volume reported for the current female World Record holder for the marathon distance at the time of writing. Her training typically consisted of two daily sessions of continuous running (50-60 min) at a relatively high intensity. She did very few long interval training sessions, but she usually did one high-intensity session of shorter intervals/sprint training (strides) per week. In the season 1978-1979 she took part in 50 competitions (ranging from 800m to marathon) of which she won 48. Her best track performance in this season was her Nordic record in the 3000 m, 8:31.75 which would have been the best time in the world in 2011 and 2012.

Key words: Expertise Interval Training, Long-Distance Running, Periodisation, Training Volume

INTRODUCTION

The outstanding female long distance runner from the 1970s and 1980s Grete Waitz (GW), born Grete Andersen the 1st of October 1953, died of cancer on the 19th of April 2011 at an

age of 57. GW started her international running career as a middle distance runner. She took part in her first international championship in the Olympic Games in Munich in 1972 where she competed in the 1500 m, but did not qualify for the final. In the European Championships in 1974 and 1978 she won bronze medals over 1500 m and 3000 m, respectively. In 1975 as well as in 1976 she set a world record over 3000 m, 8:46.6 and 8:45.4, respectively. Later in 1979 she set a new Nordic 3000 m record with the time of 8:31.75, which would have been the best time in the world in 2008, 2011 and 2012. In 1977 she won the 3000 m in the World Cup final, and in the World Cup in 1979 she was second in the same distance. She won the World Cross Country Championship five times (1978-81 and 1983). GW was nine times New York Marathon winner (1978-1980, 1982-86 and 1988) and she won the London Marathon in 1983 and 1986. In 1983 she was the first ever World Champion in Athletics, winning the marathon distance on the opening day of the first World Championships in Helsinki. In 1984 she obtained a silver medal in the marathon race in the Olympic Games in Los Angeles.

The purpose of this article is to give a description of the fantastic running career of Grete Waitz and to give special attention to the distribution of training volume and training intensity in two of her most successful years as an international long-distance runner, and compare her specific training strategies with the training practices of the most successful elite female long-distance runners of the last four decades.

TRAINING VOLUME, FREQUENCY OF TRAINING AND TRAINING INTENSITY IN LONG DISTANCE TRAINING
Training Volume and Frequency of Training
There is a consensus among coaches and researchers that the training load, determined by training volume measured as kilometres run per week (km · week^{-1}), training frequency (training units per week) and distribution of training intensity (HR in % of HR_{max}), are the major variables accounting for success in long distance running[1]. In spite of the fact that many attempts have been made to develop a long distance training model that optimizes performance[2-5], it is still a debated topic as to how training frequency, training volume and distribution of training intensity should interact in an optimal training program to best improve the level of performance among long distance runners[1,6,7].

Longitudinal investigations show a strong correlation between the total number of training hours per year and performance in elite endurance sport[8-10]. A review of the research literature shows that most successful long distance runners have workloads of 150-260 (km · week^{-1}), during a normal season[3,11-14]. High training volume is most often a result of many training units per week. High level male long distance runners typically have between 11 and 14 running sessions per week[11,13,15], and elite Kenyan male long distance runners typically do three running sessions a day[16].

Ingrid Kristiansen (IK) was the best female long distance runner in the world in the mid-1980s. In the season 1985-1986 IK held a total annual training volume of 7625 kilometres, which gives an average of 155 (km · week^{-1})[12]. Sonia O'Sullivan (SO'S) would usually run 100 miles · week^{-1} (160 km · week^{-1}). The highest number of miles that SO'S covered during one week of 1995 was 112.5 miles (180 km). During the competition period (May-September) she ran 72-75 miles · week^{-1} (115- 120 km · week^{-1})[12].

The last two decades, African male and female runners have also had success on the international circuit. Billat et al.[16] examined the training characteristics of 13 male and 7 female Kenyan elite long distance runners, and concluded that Kenyan male runners normally use either a high volume and low intensity training model (HVLI-model) or a low

volume and high intensity training model (LVHI-model), while most of the female runners use the LVHI-model. 7 male runners used the HVLI-model and 6 the LVHI-model, running an average of 174 (± 17) and 158 (± 19) km · week^{-1}, respectively. 7 of 8 female long distance runners used the LVHI-model and performed an average training volume of 127 (± 8) km · week^{-1}. Kenyan runners using the HVLI-model typically trained three times a day. Most female runners doing LVHI, however, trained once a day and not on Sunday, which was the day for church and family[16].

Training Intensity

In sport, training intensity can be expressed as an absolute entity defined as meters per second (m · s^{-1}), kilometres per hour (km · h^{-1}), minutes and seconds per kilometre or oxygen uptake ($\dot{V}O_{2max}$) per minute[17] or as a relative entity where the actual work is expressed as a percentage of what the athlete could achieve at the maximum of his or her training condition. In endurance sports it is usual to express training intensity as a percentage of; $\dot{V}O_{2max}$, maximum heart rate (HR$_{max}$), HR at the anaerobic threshold (AT) and running speed (m · s^{-1} or km · h^{-1}) over a certain distance[17] . Table 1 shows an example of a scale of intensities to be used as a reference for the training performed by international long distance runners and the longitudinal analysis of the training diaries of Grete Waitz. The table describes training intensity as a relative entity and is a modification of the intensity zones and duration of training recommended by the Norwegian Olympic Training Centre and is adjusted to long distance running according to GW's training regime[18]. The different training zones are classified according to the specific running pace (minutes per kilometre) of long distance training, $\dot{V}O_2$ in % of $\dot{V}O_{2max}$ (% $\dot{V}O_{2max}$), heart rate in % of heart rate max (% HR$_{max}$), and type of training executed in the different intensity zones.

The distribution of training volume and training intensity of international marathon runners is, as mentioned above, based on one of two basic models; model 1) training load with an average of 200-260 (km · week^{-1}), based on a high training volume at low intensity (60-75 % of $\dot{V}O_{2max}$); and model 2) training load with an average volume of 150-200 (km · week^{-1}), with a greater proportion of the running at higher intensities (80-87 % of $\dot{V}O_{2max}$). Both models have been found to be beneficial for performance at a high international level[3].

Esteve-Lanao et al.[10] conducted a longitudinal training intervention with eight Spanish long-distance runners at national level. The purpose of the study was to examine the relationship between training volume at different training intensities and performance. They found a statistical correlation between training time performed at low intensities (< 70 % of HR$_{max}$) and performance (national cross country championships). 71 % of the training volume was performed at intensities < 70 % of HR$_{max}$.

Kenyan runners use either a low volume / high intensity (LVHI) or a high volume / low intensity (HVLI) training model[16]. Most female runners use the LVHI model. These runners' training volumes were < 130 km per week. They typically trained two interval sessions per week: 1) 10-20 · 400-600 m at $\dot{V}O_{2max}$ pace (zone 5 in table 1) or 7 · 200 m at 120 % of v$\dot{V}O_{2max}$ (zone 6 in table 1). The other weekly interval session was performed at a pace between v$\dot{V}O_{2max}$ and vAT. According to Billat et al.[16] this is close to specific 10000 m velocity (zone 4 in table 1). This session could consist of 10 · 1000 m or 5 · 2000 m. Among the Kenyan female runners that have used the HVLI model, is Tegla Lourope who in 1998 and 1999 set marathon world records running 2:20:47 and 2:20:42 in Rotterdam and Berlin, respectively. In addition to running many km · week^{-1}, the HVLI runners use continuous running between 45 and 70 min at anaerobic threshold pace (vAT) as an important part of their training regime. 15 % of their total training volume consists of vAT training. In

Table 1. Training Zones, % $\dot{V}O_{2max}$, % HR_{max} and Type of Training Executed in Different Intensity Zones

Training Intensity zones Running speed	% VO_{2max}	% HR_{max}	Type of training Duration of training
Zone 1: Low intensity Zone 2: Moderate intensity Just below marathon pace and marathon pace (3:45-3:30 min.km^{-1})	60-75 % 75-82 %	65-78 % 78- 85 %	Continuous running 45-180 minutes Continuous running 45-120 minutes
Zone 3: Anaerobic threshold intensity Half marathon pace (vAT) (3:30-3:20 min.km^{-1}) Zone 4: Moderate to high intensity 10000 m pace	82-88 % 88-98 %	85-89 % 89-93 %	Anaerobic threshold training. Continuous running or longer intervals : Total load: 45-60 minutes Aerobic capacity training. Training between AT and $\dot{V}O_{2max}$. Interval-training ; 6-20 minutes: Total load: 30-45 minutes
Zone 5: High intensity (v$\dot{V}O_{2max}$) 5000 m and 3000 m pace Zone 6: Very high intensity 1500 m and 800 m pace	100 % >100 %	93-100 %	$\dot{V}O_{2max}$ training Aerobic/anaerobic mixed zone. Interval- training; 2-6 minutes: Total load: 20-30 minutes Anaerobic endurance training. (Lactic energy production) Interval training; 30-120 seconds: Total load: 10-20 minutes
Zone 7. Sub. maximal intensity 400 m pace (m/s) Zone 8: Maximal intensity Speed training— maximal pace (m/s)			Anaerobic capacity training. (Lactic energy production) Interval training: 20-60 seconds. Total load: 2-6 min Sprint-training: 5-20 seconds (Alactic energy production)

addition, runners like Tegla Lourope did one interval session such as 6 · 1 mile (1609 m) with a recovery consisting of a 200-400 m jog. According to Billat et al.[16] this is an intermediate speed between her velocity over 3000 m and 10000 m. With reference to Table 1, this is training in zone 4 (10000 m pace) and zone 5 (3000 m and 5000 m pace).

Enoksen et al.[13] found that Susanne Wigene who won the silver medal in 10000 m in the European Championship in 2006, ran an average of 170 km · week^{-1} using a HVLI model. A representative training program in the preparation period consisted of 11-12 continuous running sessions in zone 1 and 2 and one to two weekly sessions at marathon pace (zone 3) with a total running volume of up to 20 km per session[19].

The female World Record marathon runner, Paula Radcliffe, who has completed the

distance in 2:15:25, ran between 192 and 256 km · week^{-1} (120-160 miles· week^{-1}) during full marathon training. "Steady" continuous running, which was a large proportion of her total weekly km volume, was often performed at a pace between 3:40 and 3:20 min per km. She also typically included running at lactate turn-point pace (LTP) and 1-2 weekly interval sessions at a pace of 95-100% $\dot{V}O_{2max}$ in in her weekly training programme[14].

METHOD
SUBJECT
This case study of the training of nine times New York Marathon winner Grete Waitz was given voluntary consent by GW herself and her husband and coach for the majority of her career, Jack Waitz. He has also read the manuscript and gave his personal opinion about her performed training and competitions in the analysed seasons prior to publication.

The personal best times of GW for the different running distances are: 800 m: 2:03.1; 1500 m: 4:00.58; 3000 m: 8:31.75; Half Marathon: 1:08.80; and Marathon: 2:24:55. The time 8:31.75 is at time of writing, still the Nordic record.

COLLECTION OF DATA
This article is based on an analysis of GW's training diaries from her early start as a track and field athlete to her best performance years as a long-distance track runner and marathon runner. We will give special attention to her performed training and competition participation in the track season 1978-79 and marathon season 1982-1983. These are two outstanding seasons in her career. Calculations based on the training reported in her diaries were used to estimate; a) average number of training sessions per week; b) average training volume (km · week^{-1}); and c) distribution of training volume at calculated intensities / running pace (Table 1) during different training periods of the year.

The training registration protocol was based on the distribution of training into the specific intensity zones recommended by the Norwegian Olympic Training Centre[18] and consists of 8 standardized intensity zones defined in terms of $\%HR_{max}$, $\%VO_{2max}$, racing speed and duration of the training sessions (see Table 1). As GW never used heart rate monitors when training, the distribution of training in different zones are based on what GW has written in her training diaries about: a) running distance of the different sessions (kilometres and meters); b) time measurements of each session (hour and minutes) and on interviews with GW and her personal coach, Jack Waitz. 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.

To get an overview of her total running activity in the analysed seasons, we also categorized her participation in different competitions into: 1) type of competition; 2) distances; 3) total running volume; and 4) calculated running intensity/racing pace. The racing pace in competitions may vary according to the actual running distance (see Table 1).

RESULTS
TRAINING BACKGROUND
Grete Waitz started athletics at the age of 12 and competed in sprint, jumping and throwing events up to the age of 14. At the age of 15 she for the first time took part in races over 200 m. She ran her first 800 m at the age of 16. At this age she trained 5 times a week[19]. She did interval training and steady long runs up to 8 - 10 km. GW said she trained a lot with the boys and that the training intensity was relatively high already at the age of 17-18. At the age of 19 she was able to maintain a pace of 4:00 min per km on a 10 km run without it

costing much effort[19]. As a 19 year old girl GW held the following personal best records: 800 meter 2:05.7; 1500 meter 4:17.0; and 161cm in high jump.

    According to GW, her training in the season 1971 and 1972 was mainly 800 m training. She trained on average 6.9 sessions per week, and she ran an average of 83 km · week⁻¹ [19]. From November 1971 to August 1972 an average of 7.1 sessions per month were continuous running sessions longer than 10 km (11 to 14 km). 2.1 sessions per month were continuous running sessions shorter than 10 km (6 to 10 km). The remaining running sessions were mainly sessions consisting of shorter or longer interval sessions or fartlek. In the preparation- and pre-competition period (January to the end of April 1972) the following six intervals sessions were most used:

Shorter intervals with very short recovery:
    a)   30 · 200 m (recovery 10-15 sec) or b) 45 ·100 m (recovery 10-15 sec) or c) 15 · 300 m (recovery 15 sec)
Longer intervals with a long recovery:
    a)   2 · 1000 m + 2 · 800 m + 2 · 600 m (recovery 3 min) or b) 8 · 500 m (recovery 3 min) or c) 8 · 400 m (recovery 3 min)
From May to end of August 1972 these sessions were most used:
Shorter intervals:
    a)   25 · 100 m (recovery 20 sec) and b) 50 · 100 m (recovery 20 sec)
Intensive longer intervals:
    a)   3 · 1000 m in 3:10 min (recovery 5 min) and b) 2 · 600 m in 1:43-1:46 min (recovery 5 min)
Anaerobic sessions:
    a)   1 · 400 m (61 sec) + 1 · 300 m (45 sec) + 1 · 200 m (29 sec) (recovery 3 min) or b) 7 · 200 m very fast (recovery 3-4 min)
Sprint sessions: 4 · (40 m to 80 m).

TRAINING PROTOCOLS FOR THE SEASON 1973-1974

From the autumn of 1973 GW's training changed. The total volume was increased, the percentage of high-intensity sessions was dramatically decreased, and sprint training was dropped. 2-3 times per week she would run twice a day, contributing to an increase in the total number of km · week⁻¹. Analyses of GW's training diaries reveal that 1974 was the year she hit upon her particular form of training. Her training the last two weeks before the final in the European Championship in 1974 is listed in Table 3[20]. The ensuing years she increased her training volume gradually. In 1975 her average training volume for the 25 weeks after the 1st of January was 132 km · week⁻¹. This season GW achieved: 3000 m in 8:46.6 (World Record) and the 1500 m in 4:07.5. From the 1st of January 1976 she averaged 160 km · week⁻¹ during the first 25 weeks of the year. This was the period with the highest training volume throughout her career.

TRAINING PROTOCOLS FROM 1ST OF NOVEMBER 1978 TO 31st OF DECEMBER 1979

Training Volume (km · week⁻¹) and Training Frequency
Figure 1 shows km · week⁻¹ in different parts of a macro cycle, starting with the first week in November 1978 (meso-cycle 1) and ending with the last week in December 1979 (meso-cycle 5). This gives an average of 123 km · week⁻¹. The final weeks in May, the months June, July, August and September 1979 (meso-cycle 4) are not recorded in the training diary.

Table 2. The Training of Grete Waitz the Final 2 Weeks Leading up to the European Championship in Rome, from 26th of August to 8th of September 1974

	a.m.	p.m.
Monday	Track training: 1000 m (2:47.5), 600 m (1:36.1), 300 m (43.6), recovery 7:30 minutes	Continuous run 14 km
Tuesday	Continuous run 7 km	Continuous run 14 km
Wednesday	No training due to leg problem	
Thursday	20 minutes jogging	
Friday		Continuous run 13 km
Saturday	Track training: 1000 m (2:42.6), 600 m (1:34.9), 300 m (43.1), recovery 7:30 minutes	
Sunday	Continuous run 11 km	
Monday		Fartlek 11 km
Tuesday	Continuous run 8 km	
Wednesday	Shorter intensive intervals: 12 · 150 m + 10 · 100 m. Recovery 10-15 seconds, 5 min between sets.	
Thursday	25 min jogging + some strides	
Friday	4-5 km jogging	European Championship 1500 m heat: 4:11.5
Saturday	25 min jogging + some strides	
Sunday	European Championship 1500 m final, no 3: Time, 4:05.2	

However, GW's husband, Jack, confirm that the training in 1979 did not differ markedly from period to period. This was due to the fact that she competed in all months of the year. In addition to the running sessions, GW typically completed three weekly sessions of general strength training. These sessions were often carried out as circuit training. These sessions are not logged in her diary.
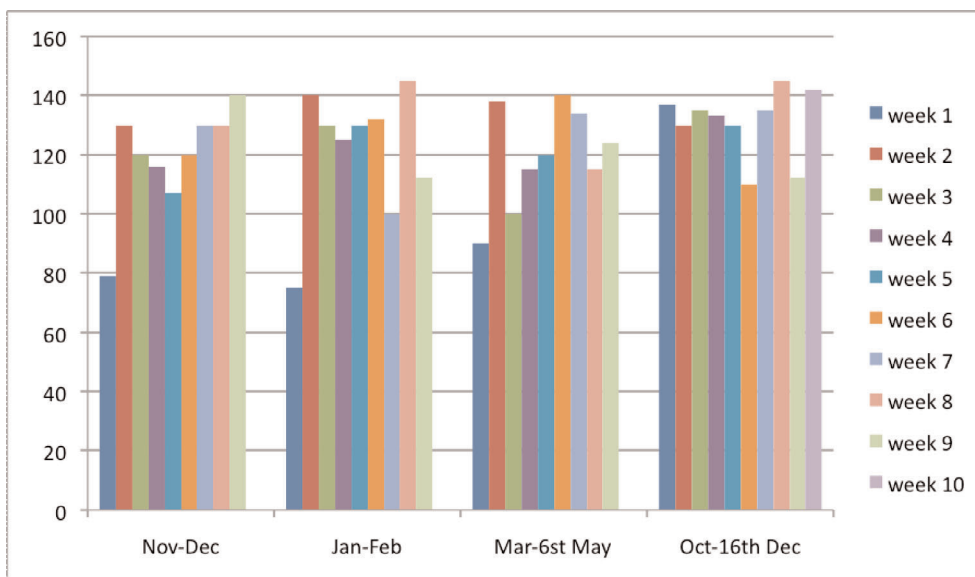

Figure 1. Km Run per Week in Different Periods of a Macro Cycle: 1978 - 1979

COMPETITIONS

GW participated in 50 competitions from 05.11 1978 to 31.12 1979, winning 48, including the World Cross Country Championships and the New York Marathon. On the track she set a Nordic record over 3000m 8:31.75 and a personal best in the 1500m (4:00.58). Table 3 describes her total competition activity in this period.

Table 3. Type of Competitions, Distances, Number of Competitions, Total Running Volume and Running Pace of the Competitions Grete Waitz Took Part in the from 1st of November 1978 to 31st of December 1979 Season 1978-1979

Type	Distances	Number of competitions	Total running volume (km)	Racing pace (intensity zones)
Track competitions Middle-distance	800 m, 1500 m, mile	16	17.3 km	zone 6
Long-distance	2000 m and 3000 m	9		zone 4 and 5
Cross Country races	2.2 km-16 km	9	50 km	zone 3,4 and5
Road races	4 km-20 km	13	125 km	zone 3,4, and 5
Park races	4 km-8 km	2	15 km	zone 4 and 5
New York Marathon	42.195 km	1	42 km	Zone 2

PERIODIZATION OF TRAINING IN THE SEASON 1978 - 1979
Meso-Cycle 1

During November and December in 1978 (9 weeks) Grete took part in 4 competitions, three cross country races ranging in distance from 2.2-4.5 km, recorded as running at 3000 m and 5000 m pace in zone 5 (table 7), and a road race over 8 km, recorded as running at 10000 m pace in zone 4 (table 7). As the road race is the only session carried out at 10000 m pace (zone 4) in this period, the average weekly volume for November and December is 0.9 km in zone 4. An example of a "typical" training week during the preparation period, November and December can be seen in table 4. Table 4 also shows how each of the training sessions is categorized into different intensity zones.

Table 4. The Training Week; 4/12 - 10/12, 1978

	a.m.	p.m.
Monday	14 km continuous running: (4:00 min/km) (zone 1)	Warm up 3 km = zone 1 + 10 · 150 m hills = zone 6 + 3 km running = zone
Tuesday		19 km continuous running (3:45-3:40) min/km = zone 2)
Wednesday	14 km continuous running (4:00 min/km = zone 1)	Warm up 3 km (3:45 min/km) + tempo runs 10 · 100 m (1 min recovery) + 5 km (4:00 min/km) 3 km (zone 2), 2000 m (zone 6), 5 km (zone 1)
Thursday		14 km continuous running (3:45-3:40 min/km = zone 2) 7 km (zone 2) + 7 km (zone 3)
Friday		10 km (4.00 min/km) (zone 1)
Saturday	5 km (4:00 min/km = zone 1)	Warm up (4 km = zone 1) + 4.5 km Cross Country Competition in London (1st place = zone 5) + 7.5 km (4:00-3:45 min/km = zone 1)
Sunday	14 km continuous running (3:40-3:25 min/km = 7 km in zone 2 + 7 km in zone 3)	

Running sessions: 10; total running volume: 120 km · week[-1]

Meso-Cycle 2

In the training period (nine weeks) from the 1st of January to the 4th of March 1979, 40 of GW's training sessions were continuous running at a pace of 4:00 min/km (zone 1, Table 7). These sessions were mainly morning sessions, typically between 7 and 15 km in distance. 46 sessions were performed as continuous running at a pace between 3:20 and 3:45 min/km. These sessions were primarily afternoon sessions (zone 2 and 3, Table 7). 8 sessions are reported to be 5-6 · 180- to 300 m at 800 m or 1500 m pace. These intensive interval sessions were typically performed after a continuous run with a length of 4 to 7 km at a pace of 3:20 to 3:45 min per km. These sessions, in addition to four competitions over 1500 m, result in an average of 3.4 km · week^{-1} (2 %) for this period recorded in zone 6 in Table 7. Three reported sprint sessions: 10 · 60 m, 3 · 100 m and 6 · 150 m are, together with strides before races, listed in zone 8 in Table 7. Three competitions over 3000 m and one 2000 m competition are registered in zone 5 (Table 7). One competition over five miles is listed as a session at 10000 m pace in zone 4.

Meso-Cycle 3

During the period from March to 6th of May GW took part in seven competitions. Two "typical" training weeks in the period March and April, leading up to the World Cross Country Championship, are shown in Tables 5a and 5b.

Table 5a. The Training Week; 12.03 - 18.03, 1979

	a.m.	p.m.
Monday		Warm up 4 km + 10 · 150 m hills + 5 km running
Tuesday		19 km continuous running (4 min/km)
Wednesday	13 km continuous running (4 min/km)	Warm up 4 km + 6 · 320 m fast, (recovery 2 min) + 4km running
Thursday	13.5 km continuous running (4 min/km)	13.5 km continuous running (3.45-3:20min/km)
Friday	13.4 km continuous running (4 min/km)	5 km + sprint 10 · 60 m (indoor hall) + 3 km
Saturday	10 km continuous running (3:45 min/km)	
Sunday	14 km continuous running (4:00 min/km)	14 km continuous running (3:45-3:20min/km)

Running sessions —11, total running volume: 13 8km · week^{-1}

Table 5b. The Training Week; 19.03 – 25.03, 1979

	a.m.	p.m.
Monday	14 km continuous running (3:45 min/km)	
Tuesday	14 km continuous running (4 min/km)	10 km (3:45-3:25 min/km) + 5 · 120 m strides
Wednesday	14 km continuous running (4 min/km)	Warm up 4 km + 5 · 320 m fast, (recovery 3 min) + 4km running
Thursday	13.5 km continuous running (4 min/km)	
Friday	Travel to Limerick	(No training this day)
Saturday		10 km continuous running (3:45 min/km)
Sunday		Warm up + World Cross Country Championship (5 km): 16:48 (1st place) + jog

Training sessions — 9, total running volume: 100 km · week $^{-1}$

For the nine weeks in this period the average weekly training volume was 120 km, and the average number of running sessions was 10. 48 sessions were carried out as continuous running at a pace of 4:00 min per km, the distances of which ranged from 6 to 19 km and are registered in zone 1 in Table 8. There were 19 sessions of continuous running at a pace between 3:20 and 3:45 min per km and recorded as zone 2 and 3 training (Table 7). The length of these runs was between 10 and 14 km. Six competitions between 2.6 and 5 km are listed in zone 5 (Table 7). 11 sessions were carried out as high-intensity anaerobic interval sessions and listed in zone 6 (Table 7). Nine of these sessions are 5-6 · 300 m with 100 m jog recovery, one session is 10 · 150 m hill running and one session is fartlek including tempo runs from 200 to 600 m.

Meso-Cycle 5
During ten weeks from the 21st of October to the end of December 1979, GW ran an average of 131 km · week^{-1}. The distribution of training in different intensity zones during these weeks is shown in Table 7. One marathon race (The New York marathon 21.10) is listed in zone 2 and a cross country competition over 20 km is listed in zone 3. Two competitions over 8 and 10 km and one session of 6 · 1000 m with 1:30 min recovery, are registered in zone 4. All other training in this period is very similar to the training carried out in the other meso-cycles of the training year. A typical week for this period, the week from 14.12 - 30.12, 1979, can be seen in Table 6.

Table 6. The Training Week; 24/12- 30/12 1979 = 142km (11 sessions), USA

	a.m.	p.m.
Monday	14 km continuous running (4:00min/km)	3 km + 8 · 500 m (2 min recovery) + 3 km
Tuesday	14 km continuous running (4:00 min/km)	14 km continuous running (3:45-3:20 min/km)
Wednesday	14 km continuous running (4 min/km)	3 km + 8 · 250 m (recovery 3 min) + 3 km
Thursday	14 km continuous running (4 min/km)	12.5 km continuous running (3:40-3:20 min/km) + 4 · 100 m strides
Friday		14 km continuous running (3:45-3:25 min/km)
Saturday		14 km continuous running (4:00 min/km)+ strides
Sunday	3 km + 8 km road race in Los Altos (1st place) + 3-4 km jog	

Training sessions — 11, total running volume: 142 km · week[1]

TRAINING PROTOCOLS FOR THE SEASON 1982 - 1983

In the season 1982-1983 GW no longer focused on track races. Road races and the marathon were now her events. During the season 1983 she won the London Marathon, the Marathon in the World Championship and the New York Marathon, in addition to the World Cross Country Championships.

Training Volume (km · week⁻¹) and Training Frequency

During 36 weeks from January to the end of August 1983 GW ran a total of 4356 km, giving an average of 121 km · week^{-1}. This training volume was distributed across 339 running sessions, which gives an average of 9.4 sessions per week. Figure 2 shows running distance in km from week to week in this period.

Distribution of Training

In spite of the fact that GW mainly competed in longer road races in 1983, her training was very similar to the training she did in 1979 when she primarily focused on track running. This is illustrated in Table 8 and 9 which show one typical training week from the preparation period (Table 8) and one week from the competition period during the 1983 season (Table 9).

Table 7. Distribution of Training at Different Intensities from November 1978 to the 21st of December 1979

| Training /Period Meso-cycles	Meso-cycle 1 Nov/Dec 1978	Meso-cycle 2 Jan/Feb 1979	Meso-cycle 3 March—6thMay 1979	Meso-cycle 5 Oct21st-Dec23rd 1979
Total km · week^{-1} in different intensity zones	121.2 km	121 km	120 km	132 km
Zone 1: Easy and moderate continuous running (3:45-4:10 min · km^{-1})	45.6 km (37.6 %)	61.1 km (50.5 %)	84.6 km (70.7 %)	64 km (48.6 %)
Zone 2: Just below marathon pace and marathon pace (3:45-3:30 min · km^{-1})	42 km (34.7%)	35.6 km (29.4%)	20.4 km (16.7%)	38.0 km (28.8%)
Zone 3: Half marathon pace (3:30-3:20min· km^{-1})	28.6 km (23.6 %)	18.7 km (15.5 %)	8.4 km (7 %)	23.8 km (18 %)
Zone 4: 10000 m pace	0.9 km (0.7%)	0.9 km (0.7%)		2.7 km (1.8%)
Zone 5: 2000 m - 5000 m pace	1.8 km (1.5 %)	0.9 km (0.7 %)	4 km (3.3 %)	1.8 km (1.4 %)
Zone 6: 800 m - 1500 m pace	1.9 km (1.5 %)	3.4 km (2.8 %)	1.9 km (1.6 %)	1 km (0.8 %)
Zone 7: 400 m pace				
Zone 8: Sprint / strides	0.4 km (0.3 %)	0.4 km (0.4 %)	0.6 km (0.5 %)	0.7 km (0.6 %)
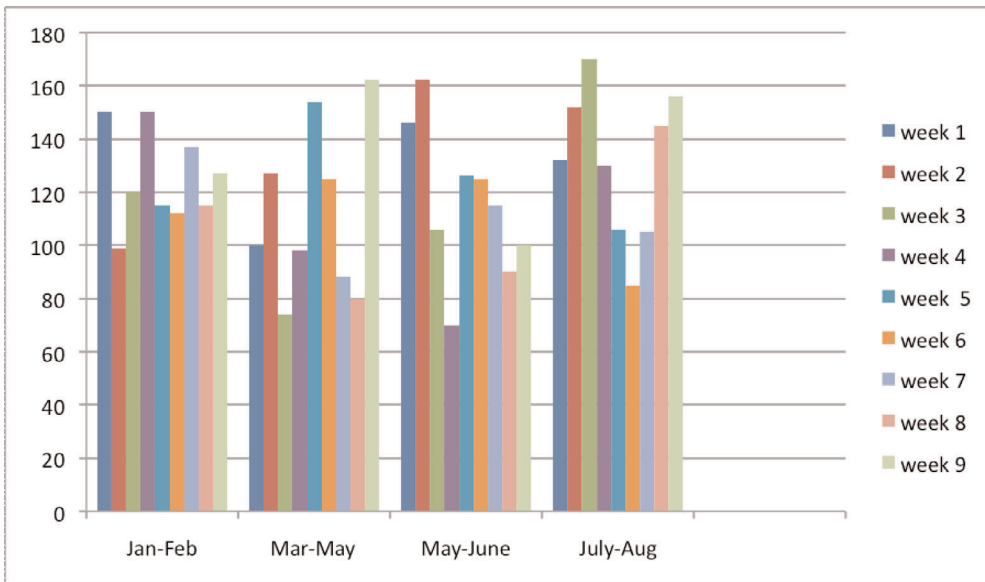
Figure 2. Km Ran per Week in DIfferent Periods of the Macro-Cycle: January 1983 to End of August 1983

Table 8. A Training Week in the Preparation Period 1983; 7/2 – 13/2 1983

	a.m.	p.m.
Monday	14km continuous running (4:00min/km)	
Tuesday	4 km + 2 · ((600 m, 400 m, 300 m, 200 m) (recovery 200 m, 100 m 200 m jog, 2 min between sets)) + 5 km	9 km continuous running (4:00 min/km)
Wednesday	14 km continuous running (4:00-3:50 min/km)	9 km continuous running (3:40-3:20 min/km)
Thursday	4 km easy running due to knee problems	
Friday	16 km continuous running (4:00min/km)	p.m: 10 km continuous running (3:40-3:20 min/km)
Saturday	12 km continuous running (3:40-3:20min/km)	15 km continuous running (4:00min/km)
Sunday	10-11 km continuous running (4:00 min/km)	4.5 km + 15 · 300m (recovery 100 m jog) + 4 km

Running sessions -12, total running volume: 137 km · week^{-1}

Table 9. A Typical Training Week in the Competition Season; 30/5- 5/6 1983 1983

	a.m.	p.m.
Monday	32 km continuous running (4:00min/km)	
Tuesday		11 km continuous running (3:4-3:20 min/km)
Wednesday	3.5 km + 10 · 300 m (recovery 30 sec) + 3.5 km	12.5 km continuous running (3:45-4:00 min/km)
Thursday	11 km continuous running (4:00min/km)	
Friday	14 km continuous running (3:40-3:20 min/km)	Travel to USA
Saturday	4 km continuous running (3:40 min/km)	12 km continuous running (3:40-3:20min/km)
Sunday	11 km continuous running (4:00 min/ km)	10 km continuous running (3:30 min/km)

Running sessions — 10, total running volume: 126 km · week[1]

DISCUSSION
TRAINING VOLUME AND INTENSITY DISTRIBUTION
The main finding in this study is that GW's total running volume in the season 1978-1979 varied from 119-132 km · week[-1] over the different meso-cycles of the training year (Table 7). If we look closer at the training volume performed by Grete Waitz (1978-1979), Ingrid Kristiansen (1986) and Sonia O'Sullivan (1995), several similarities are apparent. However, there is a marked difference in the average weekly training volume of these three athletes: Ingrid ran an average of 160 km · week[-1], Grete ran 120 km · week[-1] on average in the 1978 – 1979 season, and Sonia O'Sullivan averaged of 140 km · week[-1] [12]. It is important to underline that Grete Waitz ran 120 km as a weekly average (Figure 1 and Table 7) in the years she performed her best 1500 and 3000 m runs. There is reason to believe that this running volume is effective for achieving optimal performances in middle distance running[10,20,21]. The analysis of Grete Waitz's training for the two seasons 1978 - 1979 and 1982 - 1983 show that a higher proportion of continuous running was performed with relatively higher intensity (Tables 2, 4, 5a and 5b, 6, 7, 8 and 9) compared to Ingrid Kristiansen. Grete's documented training is more in accordance with the training of Sonia O'Sullivan. The distribution of running speed during low and moderate intensity training is

relatively similar between the two runners. However, Grete did very few long interval training sessions, while Sonia O'Sullivan performed weekly long interval sessions (eg., 5 × 1000 m) on the track in the pre-competition and competition period. Grete, on the other hand, typically ran short, high-intensity intervals once a week.

The research literature and training practices of the most successful long-distance runners of the last four decades indicate that performance development in long-distance running for women is associated with both a high training volume (km · week^{-1}) at low intensities as performed by Ingrid Kristiansen[12], Susanne Wigene[13] and Tegla Lourope[16] and a relatively low-moderate training volume (km · week^{-1}) at higher intensities as performed by Grete Waitz, Sonia O'Sullivan[12] and the majority of the Kenyan female long-distance runners[16]. According to Billat et al[16]. the Kenyan long distance runners use either a low volume / high intensity (LVHI) or a high volume / low intensity (HVLI) training model[16]. Most female runners use the LVHI model. These runners' training volumes were < 130 km per week. Most female runners doing LVHI training, however, trained once a day and not on Sundays, which was the day for church and family. The documentation of Grete Waitz's training programs show that she combined effectively a relatively low-moderate training volume with a comparatively high intensity in her daily training routines (LVHI-model). If we study her daily training we find that all her morning runs (12 km) were performed with an intensity of about 4 min/km, while her second session (13 km) was typically run at a pace of 3:45 to 3:20 min/km. The majority of her training consisted of high-quality continuous running sessions, and very seldom interval training.

Comparing GW's training to the training of the female World Record holder for the marathon at the time of writing, Paula Radcliffe (PR)[14], we see that both performed continuous running sessions at a pace between 3:40 and 3:20 per km. Both incorporated training at intensities above vAT (LTP) in their weekly training. However, the training volume (km· week^{-1}) reported for PR in full marathon training[14], was much greater than the volume of GW.

Ingrid Kristiansen's training regime, however[12], can be characterized as a high volume and low intensity training model (HVLI-model). From the training diaries of IK we understand that 88 % of her annual training volume of 7625 km was primarily training in the area classified as zone 1 in Table 1.This training strategy corresponds with a direction in the literature prioritising high training volume (160-180 km · week^{-1}) at relatively low intensities in order to perform at an international level (HVLI-model) in long distance running. This is supported by Esteve-Lanao et al.[10] who found a correlation between training time performed at low intensities (< 70 % of HR_{max}) and performance amongst eight Spanish long-distance runners at national level.

According to Billat et al.[16] Tegla Lourope who in 1998 and 1999 set marathon world records running 2:20:47 and 2:20:42 in Rotterdam and Berlin having used the HVLI-model. In addition to running many kilometers per week, Billat et al.[16] reported that 15 % of HVLI-runners total training volume consisted of continuous running between 45 and 70 min at anaerobic threshold pace (vAT). Enoksen et al.[13] found that the best Norwegian female long distance runner Susanne Wigene also developed her aerobic running capacity on a solid base of continuous running at low and moderate intensities in the preparation meso-cycle.

TRAINING PERIODIZATION, COMPETITIONS AND TRAINING METHODS
If we look more closely at the periodization of Grete Waitz training loads in the different meso-cycles of the training year, we see that the average running volume (km · week^{-1}) during the 1978-1979 season (Table 7) varied from 119 to 132 km. The reason why her

training volume was so consistent has to be viewed in connection with her year-round competition activity. In the season 1978-1979 she took part in 50 competitions. She won 48, in itself quite an amazing performance feat (Table 6). These competitions added a greater intensity and quality to her training. She participated in a variety of competitions including a high number of road runs and park runs over 5, 10 and 15 km, cross-country runs and track races from 800 m to 3000 m (Table 6). Her best track performance in this season was her Nordic record in the 3000 m – 8:31.75 (17.7.79) and her personal best over 1500 m (4:00.58). Her love of, and dependence on, competition reveals a lot about her personality, inner motivation, physical capacity and adherence as an athlete.

From Table 6 we can see that an average of just 44 % of Grete Waitz's total running volume in meso-cycles 1 and 2 during the 1978-1979 season was performed at low intensity (zone 1), 30 % was performed at and just below marathon pace (3:45-3:30 min $\cdot km^{-1}$) (zone 2) and 23 % was performed at anaerobic threshold pace (3:30-3:20 min $\cdot km^{-1}$) (zone 3).The zone 2 as well as the zone 3 sessions were performed as continuous running sessions. Running > 50 % of the total training volume at a pace from 3:45 to 3:20 min$\cdot km^{-1}$ is very fast for a female runner.

The volume of GW's training performed at different race paces, zone 4, 5, and 6 is rather small. This is due to the fact that one weekly competition over 1500 m and one weekly session of 6 · 300 m at 800 m pace contribute only a small amount of time in zone 6. GW increased the volume of running at specific marathon pace (zone 3) in the periods leading up to important championships, from 16.7 % in meso-cycle 3 (Table 7) to 28.8 % in the period leading up to The New York Marathon (meso-cycle 5, Table 7). She also increased the volume at anaerobic threshold pace (half marathon pace) from 7% in meso-cycle 3 to 18 % in meso-cycle 5. This increase in the amount of training at the anaerobic threshold gives the advantage of performing extensive quality training without an increase in blood lactate which may lead to improved aerobic capacity ($\dot{V}O_{2max}$) and improved running economy (RE). This is in line with the research of Billat et al.[22] who found that more training at specific marathon pace increased performance in elite female long-distance runners.

The rather high volume performed at anaerobic threshold pace is, however, in glaring contrast to the intensity distribution reported among German rowers preparing for the world championship[23]. These rowers, competing between 6-7 min over a 2000 m-distance, performed no rowing at threshold intensity. Instead, they trained either at low intensities (below 2 mmol lactate) or high intensities (6-12 mmol lactate).

According to Jack Waitz, the amount of training in zone 3 in meso-cycles 3 and 4 was reduced and the quality of the training increased to optimize performance, with a focus on doing more running in zone 5 and 6 (1500 m and 3000 m pace) and zone 8 (sprint and strides).

If we study the examples from the training programs of Sonia O'Sullivan[12] we find a mixture of continuous running at moderate intensity (zone 2 and 3) in all meso-cycles. Her training varied a great deal, with several interval training sessions in zone 4 and 5 each week in the preparation, pre-competition as well as in the competition period. She also used a great deal of fartlek and hill running in her preparation periods (zone 4 and 5). Examples of her long interval runs are 10 · 1000 m and 5 · 2000 m with a recovery of 1 min in the preparation period (zone 3), while she performed; e.g., 5 · 1000 m with a recovery of 2 min in the pre-competition period and 3 · 1000 m with a recovery of 5 min in the competition period. Sonia O'Sullivan's training became gradually more intensive in the pre-competition and competition period (zone 4 and 5) and the amount of training (km · week^{-1}) was reduced by 40-50 % from the preparation to the pre-competition and competition period. This structural

change in training load is in accordance with the research literature and appears beneficial in optimizing her performance potential prior to important competitions[2, 21].

In addition to running many kilometres per week, the Kenyan long distance runners typically trained two interval sessions per week 10-20 · 400-600 m at $\dot{V}O_{2max}$ pace (zone 5 in Table 1) or 7 · 200 m at 120 % of $v\dot{V}O_{2max}$ (zone 6 in table 1). The other weekly interval session was performed at a pace between $v\dot{V}O_{2max}$ and vAT. According to Billat et al.[16] this is close to specific 10000 m velocity (zone 4 in Table 1). This session could, for example, consist of 10 · 1000 m or 5 · 2000 m. In addition, runners like Tegla Lourope performed one interval session such as 6 · 1 mile with a 200-400 m jog recovery. According to Billat et al.[16] this was an intermediate speed between her velocity over 3000 m and 10000 m. With reference to Table 1, this is training in zone 4 (10000 m pace) and zone 5 (3000 m and 5000 m pace). This training regime is almost identical to that used by Norwegian runner Susanne Wigene[13].

CONCLUSION

Grete Waitz's total running volume, in her best seasons, varied from 119-132 km · week^{-1} in the different meso-cycles of the training year. Her weekly training volume is far below the volume reported for the female World Record holder for the marathon distance at the time of writing. Grete's training typically consisted of two daily sessions of continuous running (50-60 min) at a relatively high intensity. She did very few long interval training sessions, but she usually ran one high-intensity session per week consisting of short intervals/sprint training (strides).

A running volume of 120-180 km · week^{-1}, depending on the ratio of training intensity distribution, is referred to in the research literature as the average training limit for optimizing performance in long-distance running[11-13,16]. There appears to be two training paths (models) to follow if pursuing an international long-distance running career. A high volume, low intensity model (170-200 km · week^{-1}) seems best suited to male long-distance runners and female endurance running types (Paula Radcliffe, Ingrid Kristiansen, Tegla Lourope and Susanne Wigene), while a low volume, high intensity training model (120-150 km · week^{-1}) is more appropriate for female middle- and long-distance running types, such as the majority of Kenyan female runners, Grete Waitz and Sonia O'Sullivan. It is documented by Billat et al.[16] that the majority of the best female Kenyan long distance runners run an average of 130 km · week^{-1} (LVHI-model) and train less than elite men (180 km · week^{-1}) (HVLI-model). An exception is the training reported for Paula Radcliffe who combined a high training volume with rather hard continuous running and 1-2 intensive interval sessions per week[(14)]. The distribution of registered training in the various intensity zones used in this article also corresponds well with what is recommended in the research literature[5, 10, 13, 24].

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