International Journal of Sports Physiology and Performance, 2007;2:72-92

Training Characteristics of Qualifiers for the U.S. Olympic Marathon Trials

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Purpose: To describe and compare training characteristics of the 2004 U.S. Olympic Marathon Trials qualifiers. ***Methods:*** All qualifiers (104 men, 151 women) received questionnaires. Ninety-three (37 men, 56 women) responded and were categorized as elite (men <2 hours 15 minutes, women <2 hours 40 minutes) or national class. ***Results:*** Men and women ran 75% and 68% of their weekly training distance, respectively, below marathon race pace. Men trained longer than women (12.2 ± 5.3 vs 8.8 ± 5.6 years), ran more often (8.7 ± 2.8 vs 7.1 ± 2.5 times/wk), and ran farther (145.3 ± 25.6 vs 116.0 ± 26.5 km/wk). Elite women ran more than national-class women (135.8 ± 31.5 vs 111.3 ± 23.3 km/wk). Distances run at specific intensities were similar between sexes. For men and women, respectively, 49% and 31% did not have a coach and 65% and 68% trained alone. Marathon performance correlated to 5-km, 10-km, and half-marathon performance and to years training, average and peak weekly distance, number of weekly runs, and number of runs ≥32 km for women. ***Conclusions:*** Among U.S. Olympic Marathon Trials qualifiers, there is no consensus as to how to prepare for the marathon beyond running at a pace slower than race pace. Weekly training distance seems to influence women's marathon performance more than it does men's. Because many of these athletes train alone and without a coach, further research is warranted on the reasons that these athletes train the way they do.

Key Words: distance running, endurance performance, competitive, athletes, gender

Although much is known about the performances and physiology of elite distance runners, little scientific information has been published concerning their training. Among the studies documenting the training practices of distance runners, most have only examined generalizations of training,[1] such as weekly training distance,[2] or reported one or two training characteristics as accompaniment to other results that were the main focus of the studies.[3] In addition, studies that have included elite runners have been limited to small samples,[1-7] making any conclusions regarding athletes' training practices tentative at best. Furthermore, studies of elite athletes typically collected training data over a short time period, offering limited information pertaining to the long-term development of distance

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runners. For example, in 2 studies Billat et al[5,6] examined training data for only 5 to 7 runners 12 and 8 weeks before competition, respectively, time periods that would have likely included a taper of training volume typical of athletes preparing for competition. There are no studies that have examined yearlong training characteristics of endurance athletes of an Olympic Trials–caliber level, leaving much unknown about training for endurance performance.

From a cardiovascular model of exercise, it is widely accepted that endurance performance is influenced by aerobic power (VO_2max), lactate threshold, and running economy.[8] Furthermore, it is well known that these physiological variables can improve with training.[8] Although VO_2max might be more important for middle-distance events that are run close to the velocity of VO_2max, lactate threshold and running economy might be more important for the marathon.[9] Given the sparse data available on the daily training of marathoners, however, it is unknown whether their training is consistent with the relative importance of these physiological variables.

The 2004 U.S. Olympic Marathon Trials represented a unique opportunity to collect training data on the best male and female marathoners in the United States. The purpose of this study was to describe the year-round training characteristics of the athletes who qualified for the 2004 U.S. Olympic Marathon Trials and to compare the details of training during specific periods of the year between men and women and between elite and national-class athletes of each sex.

Methods

Subjects

All of the athletes who qualified for the 2004 U.S. Olympic Marathon Trials (104 men and 151 women) were asked to participate in this study. In order to compete at the Olympic Trials, the athletes had to meet a qualifying time (2 hours 22 minutes for men and 2 hours 48 minutes for women) within 2 years of the event. Each athlete was provided with a study information sheet that explained the voluntary nature and purpose of the study. All procedures of this study were approved by Indiana University's institutional review board.

Ninety-three athletes (36.5%) responded to the questionnaire (37 men and 56 women) and were used in the data analysis. Subjects' self-reported physical characteristics, and personal-best race performances are listed in Table 1. Marathon time ranged from 2 hours 9 minutes 30 seconds to 2 hours 22 minutes 4 seconds for men and 2 hours 21 minutes 16 seconds to 2 hours 47 minutes 59 seconds for women.

The athletes were divided into 2 categories—elite and national class—based on their personal record (PR) for the marathon. Women who had run under 2 hours 40 minutes (the U.S. Olympic Trials A standard set by USA Track & Field, the sport's national governing body) were categorized as elite, and those between 2 hours 40 minutes and 2 hours 48 minutes (the Olympic Trials B standard) were categorized as national class. Because there was only a 2-minute difference between the A and B standards for men (2 hours 20 minutes vs 2 hours 22 minutes), men who had run under 2 hours 15 minutes (the Olympic A standard set by the International Association of Athletics Federations, the sport's world governing body) were

Table 1 Subjects' Physical and Performance Characteristics, Mean ± SD*

	Total		Men		Women	
	Men (n)	Women (n)	Elite (<2:15) (n)	National-class (2:15–2:22) (n)	Elite (<2:40) (n)	National-class (2:40–2:48) (n)
Age (y)	30.1 ± 3.2 (37)	31.9 ± 5.4 (56)	31.1 ± 3.7 (5)	30.0 ± 3.1 (32)	31.3 ± 4.1 (11)	32.1 ± 5.7 (45)
Height (cm)	177.8 ± 6.0† (37)	163.8 ± 5.3 (56)	172.7 ± 4.7 (5)	178.6 ± 5.8 (32)	163.8 ± 5.0 (11)	163.8 ± 5.5 (45)
Mass (kg)	65.1 ± 6.3† (37)	51.1 ± 3.9 (56)	59.4 ± 2.0 (5)	66.0 ± 6.3 (32)	51.0 ± 3.9 (11)	51.2 ± 3.9 (45)
BMI (kg/m^2)	20.6 ± 1.3† (37)	19.1 ± 1.1 (56)	19.9 ± 0.7 (5)	20.7 ± 1.4 (32)	19.0 ± 0.9 (11)	19.1 ± 1.1 (45)
Marathon PR (min)	139.1 ± 3.4† (37)	162.8 ± 5.4 (56)	132.1 ± 2.2‡ (5)	140.1 ± 1.8 (32)	153.9 ± 5.0§ (11)	164.9 ± 2.4 (45)
5-km PR (min)	14.5 ± 0.5† (35)	17.0 ± 0.8 (54)	13.7 ± 0.4‡ (5)	14.6 ± 0.4 (30)	16.3 ± 0.9§ (11)	17.2 ± 0.6 (43)
10-km PR (min)	30.0 ± 1.1† (33)	35.2 ± 1.5 (53)	28.4 ± 0.8‡ (5)	30.3 ± 0.9 (28)	33.6 ± 1.8§ (11)	35.6 ± 1.2 (42)
Half-marathon PR (min)	66.4 ± 1.9† (32)	77.6 ± 3.2 (51)	63.5 ± 1.5‡ (5)	66.8 ± 1.6 (28)	74.1 ± 2.7§ (11)	78.5 ± 2.7 (40)

*Values (except for BMI) were self-reported. n indicates number of questionnaire respondents; BMI, body-mass index; and PR, personal record.

†Significantly different from women ($P < .001$).

‡Significantly different from national-class men ($P < .001$).

§Significantly different from national-class women ($P < .001$).

categorized as elite, and those between 2 hours 15 minutes and 2 hours 22 minutes were categorized as national class. Among the respondents, 5 men and 11 women were elite and 32 men and 45 women were national class. Histograms showing the number of subjects at each performance level are shown in Figures 1 and 2.

Methodology

All the Olympic Marathon Trials qualifiers received a questionnaire along with an addressed, postage-paid envelope for return to the study's principal investigator. The men received the questionnaire, along with the study information sheet, in their race packets at the site of the Olympic Trials (February 7, 2004, in Birmingham, Ala). Any men who qualified but did not participate in the Trials were mailed a questionnaire to their home address. Because it was not possible to include the questionnaire in the women's race packets at the site of their race (April 3, 2004, in St Louis, Mo), each woman who qualified, whether she participated or not, received the questionnaire in the mail at her home address. In addition to receiving the paper form of the questionnaire, an online version was posted on the Internet (www.USurveys.com) for the athletes' convenience. The athletes were contacted about the Internet version of the questionnaire by USA Track & Field and were provided with a password to access the questionnaire. Approximately 1 month after being

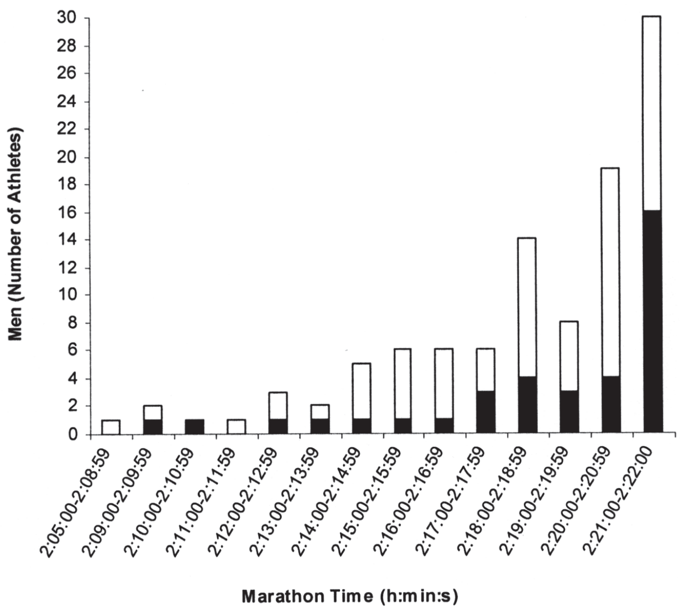

Figure 1 — Marathon performances of questionnaire respondents (black bars, n = 37) and nonrespondents (white bars, n = 67) who qualified for the 2004 men's U.S. Olympic Marathon Trials.

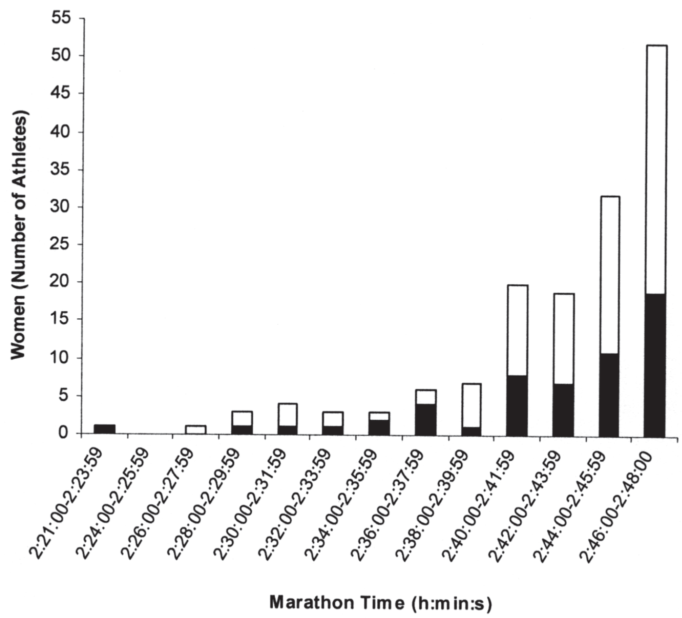

Figure 2 — Marathon performances of questionnaire respondents (black bars, n = 56) and nonrespondents (white bars, N = 95) who qualified for the 2004 women's U.S. Olympic Marathon Trials.

contacted about the Internet questionnaire, USA Track & Field sent a follow-up e-mail to all of the qualifiers in an attempt to maximize the response rate.

Questionnaires

The questionnaire was developed and revised through discussion with college cross-country coaches and physiologists, as well as from past research that examined training characteristics of elite athletes.[5,6] In addition, the questionnaire was given to athletes training for the marathon to address possible ambiguities in and the reliability of the questions. The questionnaire included questions regarding the athletes' physical characteristics (age, height, and weight), training history (use of a coach, number of years of training, use of altitude, and whether they trained alone or in a group), primary source of financial support (full- or part-time job, spousal or parental support, corporate sponsorship, and prize money), high school and college performances (1 mile/1500 m and 2 miles/3000 m), personal-best times for various distances (5 km, 10 km, half-marathon, and marathon), and training characteristics for the whole year (average and peak weekly distance, longest training run, number of runs ≥32 km, and number of days of training missed because of injury) and for each quarter of the year (weekly distance at tempo pace, goal marathon race pace, and at or faster than 10-km and 5-km race paces; frequency of training; and number of weekly interval and strength-training workouts). To obtain a clearer picture of how these marathoners train, the year of training leading up to the Olympic Trials was divided into quarters, with the fourth quarter representing the last 3 months before the Olympic Trials race.

Statistical Analysis

A one-way analysis of variance (ANOVA) was used to compare data between groups using commercially available software (SPSS®, version 12.0, Chicago, Ill). For nominal data, a chi-square test was used. Pearson correlational analysis was used to determine the strength of relationship between each athlete's marathon PR and high school and college PRs; between marathon PR and PRs for 5 km, 10 km, and half-marathon; and between marathon PR and training characteristics. In addition, the training data were analyzed using stepwise multiple regression to determine the significant predictors of marathon performance for men and women. For all tests, statistical significance was set at $P < .05$, with a Bonferroni adjustment made for multiple comparisons.

Results

Physical and performance characteristics are listed in Table 1. Although physical traits differed between men and women, they were similar between elite and national-class athletes. There was no relationship between marathon performance and age, height, or body mass for men or women.

The weekly training volume of the Olympic Trials qualifiers and their numbers of weekly workouts are listed in Table 2. Men had been training for more years than women and ran a significantly greater average and peak weekly distance. Among performance levels, elite women, but not elite men, had been training for more years, ran a greater average and peak weekly distance, and ran more often than their national-class counterparts. In addition, elite men did more strength training than national-class men. Collectively, however, these runners included little strength training in their training programs, with the men averaging less than 1 and the women averaging less than 2 strength-training workouts per week throughout the year. Nearly half the runners did no strength training at all. There was no difference between men and women or between elite and national-class athletes of either sex in the number of training days missed because of illness or injury.

As Table 3 shows, the average volume of training performed at different intensities was similar between the sexes and between elite and national-class athletes but varied substantially at the individual level, as indicated by the large standard deviations. For all athletes, the large majority of training was performed at slower than marathon race pace, with men running 74.8% (elite 75.9%, national class 74.9%) and women running 68.4% (elite 70.7%, national class 67.8%) of their weekly distance at a pace slower than marathon race pace.

Table 4 lists the frequency of responses for the questions pertaining to coaching, training status, altitude, dietary habit, and source of income. None of these variables was related to sex. Nevertheless, almost one half (49%) of men and one third (31%) of women did not have a coach. In addition, except for source of income, responses were not related to performance level for either sex. None of the 5 elite men and only 5 of the 11 elite women had full-time jobs.

Table 2 Yearlong General Training Characteristics of U.S. Olympic Marathon Trials Qualifiers, Mean ± SD

	Total		Men		Women	
	Men (n)	Women (n)	Elite (n)	National-class (n)	Elite (n)	National-class (n)
Years training*	12.2 ± 5.3† (37)	8.8 ± 5.6 (54)	16.8 ± 3.6 (5)	11.4 ± 5.2 (32)	12.3 ± 5.6§ (11)	8.0 ± 5.3 (43)
Avg. weekly distance, km	145.3 ± 25.6† (32)	116.0 ± 26.5 (48)	155.6 ± 9.3 (3)	144.2 ± 26.5 (29)	135.8 ± 31.5§ (9)	111.3 ± 23.3 (39)
Peak weekly distance, km	192.9 ± 27.7† (32)	152.2 ± 30.9 (48)	203.2 ± 38.1 (3)	191.8 ± 27.0 (29)	180.0 ± 38.3§ (9)	145.8 ± 25.3 (39)
Longest run, km	40.2 ± 8.8 (32)	37.8 ± 3.5 (48)	36.5 ± 3.7 (3)	40.7 ± 9.2 (29)	38.1 ± 4.2 (9)	37.8 ± 3.4 (39)
# of runs ≥32 km	17.7 ± 15.0† (32)	10.4 ± 9.0 (48)	7.7 ± 5.9 (3)	18.7 ± 15.4 (29)	11.9 ± 14.9 (9)	10.0 ± 7.2 (39)
# of weekly runs	(31)	(47)	(2)	(29)	(9)	(38)
1st quarter	8.1 ± 2.8†	6.1 ± 2.9	12.5 ± 0.7‡	7.8 ± 2.6	8.9 ± 2.5§	5.5 ± 2.5
2nd quarter	8.6 ± 3.0†	7.1 ± 2.8	13.0 ± 1.4	8.3 ± 2.8	10.1 ± 2.1§	6.4 ± 2.5
3rd quarter	9.3 ± 3.1†	7.2 ± 2.8	12.5 ± 0.7	9.1 ± 3.1	9.3 ± 3.0§	6.7 ± 2.5
4th quarter	8.7 ± 3.2	8.0 ± 2.8	11.0 ± 1.4	8.6 ± 3.2	10.5 ± 2.2§	7.3 ± 2.6

*Years training was defined on the questionnaire as how many years the focus of running had been to train for endurance events.
†Significantly different from total women ($P < .05$).
‡Significantly different from national-class men ($P < .05$).
§Significantly different from national-class women ($P < .05$).

For both men and women, marathon PR was significantly correlated to 5-km, 10-km, and half-marathon performance (r = .71, .73, and .72 for men and r = .68, .68, and .73 for women, respectively; all P < .001). In addition, marathon time was significantly correlated to college 3000-m performance for men (r = .58, P = .001) and women (r = .44, P = .01) and college 1500-m performance for women (r = .44, P = .01). Women's marathon PR was also significantly correlated to the number of years training (r = –.40, P = .003), average weekly distance (r = –.47, P = .001), peak weekly distance (r = –.51, P < .001), and number of runs ≥32 km (r = –.36, P = .01).

Discussion

Despite the seemingly low questionnaire response rate (36.5%), the sample obtained was representative of the population of U.S. Olympic Trials qualifiers (Figures 1 and 2). Even among the elite athletes, of the 6 who made the Olympic marathon team, 3 responded to the questionnaire. Because elite athletes represent a small segment of the population, the number of athletes in the elite groups (5 for men and 11 for women) are, by definition, small.

Physical Characteristics

Average height, body mass, and body-mass index for U.S. men and women,[10] respectively, are 175.6 and 161.8 cm, 82.1 and 69.2 kg, and 26.6 and 26.5 kg/m^2. Although not a statistical comparison, Olympic Marathon Trials qualifiers of both sexes seem to be of average height compared with the general U.S. population, but they weigh less and have a lower body-mass index (Table 1). The lower body mass of the marathoners is undoubtedly a result of the need to transport their body mass over a long distance and the energy-economical, thermoregulatory, and shock-attenuating advantages gained by being as light as possible.[11]

Physical characteristics do not seem to influence marathon performance among U.S. Olympic Marathon Trials qualifiers; elite athletes' height and body mass were similar to those of national-class athletes (Table 1). Elite women were taller and heavier and had a slightly higher body-mass index than that reported by Sparling et al[1] for a group of elite U.S. female long-distance runners competing in the 1980s (Table 5).

Although chronological age was similar between men and women and between performance levels, the elite athletes had been training 4 to 5 years longer than their national-class counterparts, although this difference was significant only for women. Given the time it takes to adapt to endurance training, it is possible that athletes need more time to train to achieve elite-level status in the marathon.

Training Characteristics

It is evident that these athletes, despite their relative homogeneity in performance and their elite status among the nation's marathoners, trained very differently from one another. To prepare for the Olympic Trials, the men averaged 145.3 ± 25.6 km/wk and the women averaged 116.0 ± 26.5 km/wk for an entire year (Table 2). These training volumes are similar to those reported from earlier studies—Pollock[7]

Table 3 Yearlong Specific Training Characteristics of U.S. Olympic Marathon Trials Qualifiers, Mean ± SD*

	Total		Men		Women	
	Men	Women	Elite	National	Elite	National-class
Weekly distance (km) at marathon pace, n	30	42	2	28	8	35
1st quarter	8.5 ± 10.5	6.3 ± 9.3	11.3 ± 6.8	8.2 ± 10.6	4.7 ± 7.7	7.6 ± 10.6
2nd quarter	11.3 ± 11.3	10.3 ± 13.0	14.5 ± 2.3	11.1 ± 11.6	11.1 ± 14.6	11.1 ± 13.8
3rd quarter	17.1 ± 16.9	17.1 ± 16.6	11.3 ± 6.8	17.4 ± 17.4	18.3 ± 22.0	17.2 ± 15.4
4th quarter	16.6 ± 18.3	20.3 ± 16.4	11.3 ± 6.8	16.9 ± 19.0	24.6 ± 30.9	20.1 ± 12.1
% Yearly distance	9.7	12.8	7.5	9.9	12.1	13.0
Weekly distance (km) at tempo pace, n	30	42	3	27	8	35
1st quarter	9.7 ± 11.1	7.7 ± 8.5	17.7 ± 12.7	8.7 ± 10.9	9.3 ± 7.2	8.0 ± 9.8
2nd quarter	13.4 ± 12.7	11.3 ± 9.3	18.8 ± 5.6	12.7 ± 13.2	13.0 ± 8.2	11.7 ± 10.8
3rd quarter	17.1 ± 13.2	15.0 ± 11.9	22.5 ± 8.5	16.4 ± 13.7	14.2 ± 3.4	15.8 ± 13.4
4th quarter	16.9 ± 13.7	19.1 ± 15.4	19.8 ± 4.0	16.6 ± 14.3	18.2 ± 3.1	19.5 ± 16.9
% Yearly distance	10.3	12.3	12.6	10.0	10.2	12.8

Weekly distance (km) at ≥10-km pace, n	30	41	2	28	8	34
1st quarter	7.2 ± 6.0	5.0 ± 6.8	10.5 ± 3.4	7.1 ± 6.0	9.0 ± 6.3	4.3 ± 6.9
2nd quarter	7.2 ± 7.1	5.8 ± 6.9	4.0 ± 5.6	7.4 ± 7.2	10.5 ± 9.3	5.3 ± 7.6
3rd quarter	7.2 ± 7.4	7.7 ± 7.7	4.0 ± 5.6	7.4 ± 7.6	9.5 ± 4.8	7.7 ± 8.7
4th quarter	6.1 ± 5.1	8.5 ± 6.8	7.2 ± 1.1	6.1 ± 5.3	9.5 ± 4.8	8.7 ± 7.6
% Yearly distance	5.2	6.5	4.0	5.2	7.0	6.4
Weekly distance (km) at ≥5-km pace, n	30	41	2	28	8	34
1st quarter	5.3 ± 3.7	3.1 ± 4.2	3.2 ± 4.5	3.7 ± 3.9	6.3 ± 5.3	2.7 ± 4.2
2nd quarter	4.7 ± 4.7	4.3 ± 5.3	0.0 ± 0.0	5.0 ± 4.7	8.2 ± 6.4	4.3 ± 6.9
3rd quarter	3.9 ± 4.8	5.6 ± 7.1	0.0 ± 0.0	4.0 ± 4.8	5.3 ± 5.8	6.3 ± 8.0
4th quarter	3.7 ± 5.1	5.8 ± 5.5	3.2 ± 4.5	3.7 ± 5.1	6.8 ± 5.3	5.8 ± 5.8
% Yearly distance	3.0	4.8	1.0	3.1	5.5	4.7

*Marathon pace was defined on the questionnaire as goal race pace for that distance. Tempo pace was defined as 10-mile to half-marathon race pace. 10-km and 5-km paces were defined as current race paces for those races.

Table 4 Frequency of Responses of Athletes for the Year Preceding the 2004 U.S. Olympic Marathon Trials

	Total		Men		Women	
	Men (n = 37)	Women (n = 56)	Elite (n = 5)	National-class (n = 32)	Elite (n = 11)	National-class (n = 45)
Full-time job, n (%)	23 (62.2)	32 (57.1)	0* (0)	23 (71.9)	5* (45.5)	27 (60.0)
Trained with coach, n (%)	19 (51.4)	38 (69.1)†	3 (60)	16 (50.0)	9 (81.8)	29 (65.9)‡
Trained alone, n (%)	24 (64.9)	38 (67.9)	3 (60)	21 (65.6)	7 (63.6)	31 (68.9)
Trained alone and without coach, n (%)	17 (46)	16 (29)	2 (40)	5 (47)	2 (18)	14 (32)
Trained at altitude, n (%)	9 (24.3)	9 (16.4)†	3 (60)	6 (18.8)	1 (9.1)	8 (18.2)†
Vegetarian, n (%)	2 (5.4)	5 (8.9)	0 (0)	2 (6.3)	0 (0)	5 (11.1)

*Significantly different from national-class ($P < .05$).
†N = 55.
‡N = 44.

reported that elite male U.S. marathon runners of the 1970s ran 162.0 km/wk, and Sparling et al[1] reported that elite female U.S. long-distance runners of the 1980s ran 120.4 km/wk. There was great variability in the training data in the present study, with high standard deviations for almost every training item on the questionnaire (Tables 2 and 3). These descriptive data cannot distinguish between successful individual optimization of training characteristics. Despite the variability in the volume of training performed, a similar pattern of training seems to emerge between men and women, with the amount of training performed at tempo pace (defined on the questionnaire as 10-mile to half-marathon race pace, used to represent the speed at the lactate threshold) and marathon pace increasing throughout the year, as time got closer to the Olympic Trials race (Figures 3 and 4). Thus, these athletes, despite running different amounts, do seem to conform to an expected training pattern, spending more time training at specific race-pace intensities as they approached the Olympic Trials.

It is interesting that most of the athletes' training consisted of low-intensity distance running, with men running 74.8% and women running 68.4% of their training at a pace slower than marathon pace (Table 3). The tendency to perform most training at a low intensity is a common finding of studies on elite endurance

Table 5 Studies Reporting Physical and Training Characteristics of Elite and National-Level Female Distance Runners*

Study	Nationality	n	Height, cm	Body mass, kg	BMI, kg/m^2	Years training	Distance per week, km	Runs per week	LSD, % of training	Weekly distance at MP (km)	Weekly distance at LT pace (km)	Weekly distance at ≥10K pace (km)
Bale et al[4]	Great Britain	11 elite	166.4	54.7	19.8	9.3	105.7	9.9	61.1	—	—	—
		12 good	163.9	51.2	19.1	6.4	76.1	7.2	66.6	—	—	—
		13 avg.	161.3	53.0	20.4	2.9	61.9	5.7	64.6	—	—	—
Billat et al[5]	France, Portugal	5 top class	164	50.2	18.7	—	166.0	12.2	77.0	12.1 (7.3)	11.3 (6.8)	14.8 (8.9)
		5 high level	161	49.2	19.0	—	150.0	10.4	80.3	9.0 (6.0)	8.2 (5.5)	12.4 (8.3)
Billat et al[6]	Kenya	6 high-speed training	168	47.8	16.9	11.0	127.0	10–16	—	—	0 (0)	14.8 (11.7)
Sparling et al[1]	United States	7 elite middle-distance	161.3	46.9	18.0	11.3	84.3	—	—	—	—	—
		7 elite long-distance	161.1	46.7	18.0	11.4	120.4	—	—	—	—	—

*Numbers represent average data (with percentage of training in parentheses). BMI indicates body-mass index; LSD, Long, slow distance running; MP, marathon pace; and LT, lactate threshold.

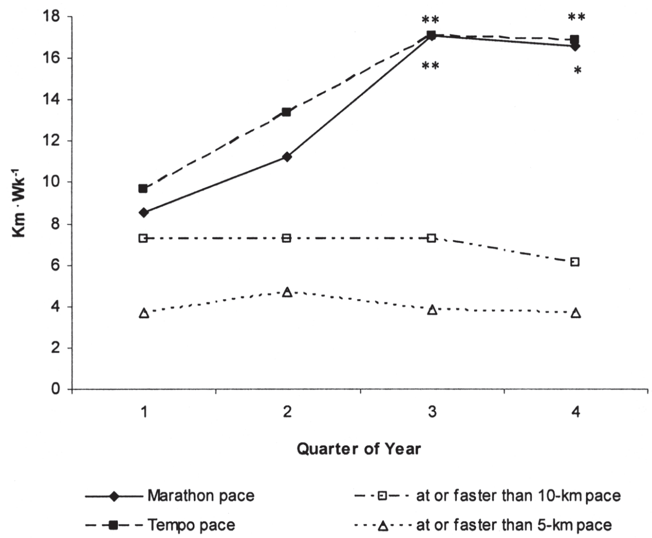

Figure 3 — Progression of men's weekly training distance at different intensities for the year preceding the 2004 Olympic Marathon Trials. *Significantly different from first quarter ($P < .05$). **Significantly different from first and second quarters ($P < .05$).

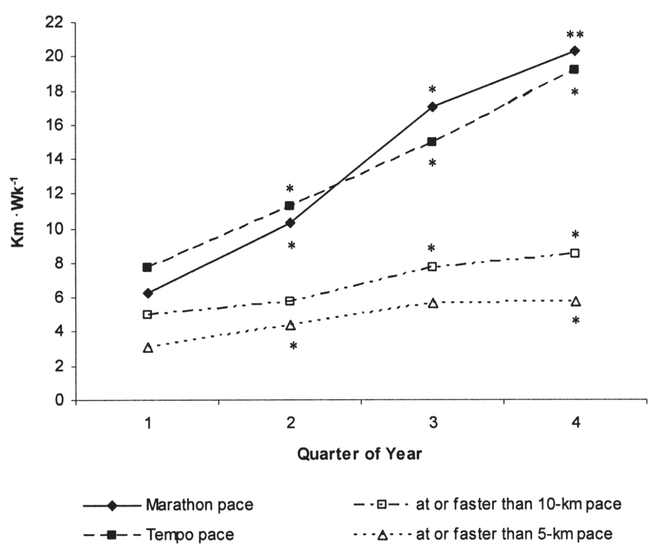

Figure 4 — Progression of women's weekly training distance at different intensities for the year preceding the 2004 Olympic Marathon Trials. *Significantly different from first quarter ($P < .05$). **Significantly different from first and second quarters ($P < .05$).

athletes.[2,4,5,12,13] There are many opinions among runners and coaches concerning optimal training methods, but most agree that training volume is important, especially for the marathon. The rather high percentage of training performed at a low intensity likely reflects this belief.

Although it makes practical sense, from a specificity-of-training perspective, to train at race pace, this does not seem to be the strategy of U.S. Olympic Marathon Trials qualifiers; men averaged only 9.7% and women 12.8% of their yearly training at marathon pace (Table 3). Furthermore, despite the importance of the lactate threshold to distance-running performance[8] and the closeness of its corresponding speed to marathon race pace, men averaged only 10.3% and women 12.3% of their training at lactate-threshold (tempo) pace (Table 3). This surprising finding is in agreement with the results of Seiler and Kjerland,[13] who found that elite Norwegian junior cross-country skiers performed only 5% of their training at lactate-threshold intensity.

The marathoners included very little high-intensity running (ie, weekly distance run at ≥10-km race pace) in their training programs, averaging only 1 interval workout a week throughout the year. This training habit might reflect the common opinion among coaches and physiologists that VO_2max, though important to marathon performance, is not as important as lactate threshold and running economy.[8,14] The athletes of this study still might not be attending to their aerobic power as much as they could to acquire the greatest benefit, however, given that interval training performed at 90% to 100% VO_2max is the most potent stimulus for its improvement.[8,15] On the other hand, it is possible that the scientific understanding of marathon performance has not yet caught up with the training practices of elite athletes (ie, the goal of training might be something other than or in addition to improving VO_2max) and that these athletes are actually doing what they should be doing to optimize their performance. Given that training volume affects training intensity, it is likely that the low amount of intense training performed by these athletes is a result of their high training volume. To train for the marathon, these athletes seemed to have made the decision, consciously or subconsciously, to forsake high intensity in favor of high volume. Although the most effective training strategy for the marathon is unknown, a high training volume might be necessary. For example, Scrimgeour et al[16] found that runners training more than 100 km/week had significantly faster running times in races ranging from 10 to 90 km than those who ran less than 100 km/week. In this study, however, as in other studies, training volume was assessed only for a short time period (3 to 5 weeks before competition), leaving much unknown about long-term training for success in endurance events.

Although not a statistical comparison, it appears that U.S. marathoners perform more training at marathon pace and lactate-threshold pace than distance runners from other parts of the world but train less at higher intensities (Tables 3, 5, and 6). This also seems to be the case compared with athletes in other endurance sports. The distribution of training intensity for men and women of the present study was 75-10-10-5-3% and 68-13-12-7-5% for intensities below marathon race pace and at marathon race pace, lactate-threshold pace, ≥10-km race pace, and ≥5-km race pace, respectively. This distribution is skewed to the lower intensities compared with the 75-5-20% distribution (below, at, and above lactate-threshold intensity, respectively) found by Seiler and Kjerland[13] for elite junior Norwegian cross-country skiers. Although it is difficult to claim that the success of international endurance athletes is a result of their high percentage of training at high intensities, it is possible that training at high intensities contributes to their performances. For example, Coetzer et al[3] found that elite Black South African runners who trained at a higher average intensity than their White counterparts were able to sustain a higher percentage of their VO_2max during races of longer than 5 km. The Black runners also had a significantly lower blood-lactate concentration after submaximal and maximal exercise and had a significantly longer time to fatigue during repetitive quadriceps isometric contractions. Although not claiming cause and effect between the athletes' training and these physiological and performance differences, the authors concluded that Black South African runners have a fatigue resistance superior to that of their White counterparts. Although a high weekly training distance at submaximal intensities improves endurance performance by increasing capillary and mitochondrial volumes,[17] training at a high intensity is more effective for increasing VO_2max,[15] probably because of its cardiovascular effects. Adding interval training to elite distance runners' training programs has been shown to further improve endurance performance.[18]

Men Versus Women

Men ran significantly more than women. Average weekly distance, peak weekly distance, number of training runs ≥32 km, and number of weekly training runs were all significantly greater for men than for women (Table 2). Previous studies of elite or national-class distance runners also reported that men ran significantly more than women.[5,6] There are a number of potential reasons for this finding. First, although it has been over 20 years since the marathon was added to the women's Olympic program, there might still be a lingering belief that women are at a greater risk for injury than men and therefore should not run as much as men. Nonetheless, female runners do not seem to have a greater risk of stress fractures than their male counterparts as long as they do not have 1 or more of the 3 characteristics of the female-athlete triad (menstrual irregularities, disordered eating, and osteoporosis) or have a body-mass index less than 21 kg/m^2.[19] In addition, the men's U.S. Olympic Marathon Trials qualifying time is a more difficult standard to obtain than the women's qualifying time. The men's qualifying time was 13.6% (17 minutes) slower than the men's world record, and the women's qualifying time was 24% (32.5 minutes) slower than the women's record. Thus, men had to attain a better performance relative to the world record than women did in order to qualify. The more difficult men's standard is likely a result of their greater depth of competition. For example, although 99 men were within 13.6% of the men's marathon world record, only 9 women were within an equivalent percentage of the women's world record. Other potential influences of training distance might include time to train, coaches' prescriptions, and prior training experience. The questionnaire did not address why the athletes ran the amount they did or why they did not run more. Exactly why women ran less than men certainly represents an area for future research.

Men and women ran similar amounts at specific intensities during the 4 quarters of the year (Table 3). This is in contrast to the findings of Billat et al,[5] who reported that men ran a significantly greater weekly distance at half-marathon, 10-km, and

Table 6 Studies Reporting Physical and Training Characteristics of Elite and National-Level Male Distance Runners*

Study	Nationality	n	Height, cm	Body mass, kg	BMI, kg/m²	Years training	Distance per week, km	Runs per week	LSD, % of training	Weekly distance at MP (km)	Weekly distance at LT pace (km)	Weekly distance at ≥10K pace (km)
Bale et al[2]	Great Britain	20 elite	175.1	64.4	21.0	8.1	109.1	10.7	59.5	—	—	—
		20 good	179.9	66.3	20.5	5.2	92.5	7.3	76.5	—	—	—
		20 avg.	173.5	69.2	23.0	3.3	61.3	4.8	87.0	—	—	—
Billat et al[5]	France, Portugal	5 top class	172	60.2	20.3	—	206.0	13.0	77.5	8.0 (3.9)	18.0 (8.7)	12.2 (5.9)
		5 high-level marathon runners	172	59.3	20.0	—	168.0	11.5	77.8	7.1 (4.2)	12.6 (7.5)	10.5 (6.3)
Billat et al[6]	Kenya	6 high-speed training	170	53.8	18.6	11.3	158.0	10–16	—	—	10.8 (6.8)	14.6 (9.2)
		7 low-speed training	173	56.7	18.9	12.0	173.9	10–16	—	—	25.4 (14.6)	3.9 (2.2)
Coetzer et al[3]	South Africa	11 Black runners	168.9	56.0	19.6	—	~90	—	~64.4	—	—	—
		9 White runners	181.3	69.9	21.3	—	~84	—	~86.5	—	—	—
Pollock[7]	United States, Ireland, Kenya	12 elite middle-/long-distance	—	—	—	—	121.3	—	—	—	—	—
		8 elite marathoners	—	—	—	—	162.0	—	—	—	—	—

*Numbers represent average data (with percentage of training in parentheses). BMI indicates body-mass index; LSD, Long, slow distance running; MP, marathon pace; and LT, lactate threshold.

3-km race paces than did women during the final 12 weeks before their subjects' Olympic Marathon Trials, with the exception being marathon pace, for which men and women ran similar amounts. This difference in findings might be explained by differences in sample size, because the study by Billat et al[5] included only 10 men and 10 women with little variability in the data. The men of the present study underwent similar amounts of high-intensity training throughout the year, but the women slightly but significantly increased their amount of high-intensity training (Figures 3 and 4). Thus, it seems that these athletes, especially the men, did not use a traditional periodized method of training, during which the volume of training decreases and the intensity increases as the most important competition draws nearer. Although it has been documented that athletes in power- and speed-dependent sports use a periodization model of training,[20-24] information on whether endurance athletes do so is lacking. In addition, not all of the athletes planned their training solely or principally around the Olympic Trials race. Because many of these athletes ran other marathons during the year preceding the Olympic Trials in an attempt to qualify, the pattern of training would likely have been influenced by the dates of those other marathons. Many of the athletes qualified more than a year before the Olympic Trials, so their training during the year preceding the Olympic Trials would have been influenced solely by that race because it would have been the focus of their training. Between the need to qualify and differences in courses, climate, and level of anxiety between races, many of the athletes ran a faster marathon to qualify than they did at the Olympic Trials.

Elite Versus National-Class Athletes

It seems that amount of training has a greater influence on marathon performance for women than it does for men—a number of training characteristics were significantly different between elite and national-class women but not between elite and national-class men. For example, at the time of the Olympic Trials race, elite women had been training for more years than their national-class counterparts (Table 2). Bale et al[4] and Christensen and Ruhling[25] also reported that better runners had been training longer. In addition, although elite and national-class men ran similar average and peak amounts, elite women ran a significantly greater average and peak weekly distance than national-class women (Table 2). This latter finding is in agreement with Bale et al,[4] who reported that better female runners ran a greater weekly distance, and in contrast to Billat et al,[5] who found no difference in the weekly training distance between elite and national-class women. The frequency of training also seems to be important—it is clear that the better female marathoners run more often. Although elite men also ran more times per week than national-class men, the difference was significant only for the first quarter of the year (Table 2). It is not clear from these data, however, whether running more often makes one a better marathoner or that better marathoners are simply capable of running more often. It is possible that the elite runners, having more training experience, have improved their ability to tolerate a more frequent training schedule. Alternatively, how often these marathoners run might simply result from differences in available time—the national-class athletes were more likely than the elite athletes to have full-time jobs (Table 4).

In regard to the athletes' training at specific intensities, there was no difference in the number of kilometers run at any intensity between performance levels for either sex (Table 3). Expressed another way, the distribution of training intensity was similar across performance levels (elite men, 76-7-13-4-1%; national-class men, 75-10-10-5-3%; elite women, 71-12-10-7-6%; national-class women, 68-13-13-6-5%). This finding is in contrast to that of others who have reported that elite male runners ran a greater weekly distance at high intensities than runners of a slightly lower performance level.[2,5]

Training Conditions

An interesting finding of this study is the number of Olympic Trials qualifiers who either did not have a coach or trained alone during the year preceding the Trials. Only 51% of men and 69% of women trained with a coach, and 65% of men and 68% of women trained alone (Table 4). Combining these 2 conditions, 46% of men and 29% of women trained alone and without a coach. A greater percentage of elite women had a coach than did their national-class counterparts (82% vs 66%, respectively). This finding is in agreement with Bale et al,[4] who reported that over 80% of elite female marathoners had coaches, compared with 67% of "good" and 31% of "moderate" runners. Although it is tempting to believe that having a coach can improve an athlete's performance, from these data it is not clear whether the coached runners became faster with a coach or that the faster runners were simply more likely to seek out a coach.

The finding that many of these athletes train alone and without a coach is in contrast to the situation in other Olympic individual sports such as swimming, speed skating, gymnastics, and cycling, which are completely team or club based. It is unheard of for Olympic Trials–caliber athletes in those sports to train by themselves and without a coach. One of the reasons that this might be the case in distance running is the lack of equipment or facilities needed for training. Regardless, this finding might represent an area in which this group of marathoners can improve their performance.

Altitude

Altitude training was also not a strategy used by the marathoners—only 24% of men and 16% of women trained at altitude, and they did so only because they resided there. There was no difference in marathon performance between athletes who trained at altitude and those who did not. Although many coaches and athletes attribute much of the success of the East African distance runners to their altitude training, there is little evidence that training at altitude is superior to training at sea-level for improvements in maximal oxygen uptake or sea-level performance.[26,27] There is some evidence that living at altitude and training at sea-level (ie, the "live high/train low" model) can improve sea-level performance[28] by inducing the erythropoiesis associated with altitude exposure while maintaining sea-level training intensities. Historically, the best U.S. distance runners (with a few exceptions) have been born and trained at sea level. Therefore, it is unlikely that the lack of altitude training among U.S. marathoners is the reason for their apparent inferiority to their East African counterparts.

Correlations

As expected, marathon PR was significantly correlated to 5-km, 10-km, and half-marathon PRs. Noakes et al[29] also found that 10-km and half-marathon performances were the best predictors of marathon performance. Because success in running events lasting longer than 3 minutes primarily depends on aerobic metabolism, it stands to reason that those who are fastest at 5 km and 10 km are also fastest in the marathon. It is interesting to note that the 6 runners who made the 2004 U.S. Olympic marathon team were the 6 fastest runners in the United States at 5,000 and 10,000 m.

It seems that the details of training, as shown in Tables 2 and 3, have a greater influence on marathon performance for women than for men. Women's marathon PR was moderately, but significantly, correlated to number of years training ($r = -.40$, $P = .003$), average weekly distance ($r = -.47$, $P = .001$), peak weekly distance ($r = -.51$, $P < .001$), number of runs ≥32 km ($r = -.36$, $P = .01$), and number of weekly runs and interval workouts ($r = -.64$ and $-.32$, respectively), but the correlations were nonsignificant for men. Of these variables, number of weekly runs explained the greatest amount of variance (41%) in marathon performance for women. These correlation coefficients are similar to those reported by Bale et al[4] between women's marathon performance and number of years training, average weekly distance, and number of weekly runs ($r = -.48$, $-.56$, and $-.63$, respectively). The lack of significant correlations between marathon performance and training characteristics for men is in contrast to Bale et al,[2] who reported high correlations between 10-km performance and number of years training ($r = -.70$), average weekly distance ($r = -.84$), and number of weekly runs ($r = -.87$). The difference in findings between the present study and that of Bale et al[2] and, more important, between the men and women of the present study is likely a result of the smaller sample size of their study and the greater degree of homogeneity in performance of the men in the present study.

None of the training variables were a significant predictor of marathon performance for men, indicating that either multiple factors might be responsible for men's marathon performance or that there was simply too much variability in the data to predict marathon performance from the training variables. For women, average and peak weekly distance and number of years training were the only significant predictors ($r = .67$), together explaining nearly 45% of marathon performance. Using these variables, a regression equation was developed using 48 subjects to predict marathon performance for the women's Olympic Trials qualifiers:

$$\text{Marathon time} = -0.135(\text{average weekly distance}) - 0.042(\text{peak weekly distance}) - 0.477(\text{number of years training}) + 180.194$$

where marathon time is in minutes.

Practical Applications

The findings of this study might help coaches understand the volume and intensity of training that it takes to achieve national- or elite-level status in the marathon.

The science of training and performance often lags behind the training practices of elite athletes, so these findings might also help scientists understand how much and what types of training influence marathon-running performance.

The fact that many of these athletes train alone and/or without a coach, an anomaly among Olympic sports, is a certain beckon for the need to organize coached training groups for marathoners who exhibit potential.

Future research should focus on the reasons that these athletes train the way they do. Particularly in the case of athletes who trained without a coach, the obvious question to be examined is, How do these athletes obtain information on training? In addition, adding physiological and psychological measurements to accompany the training characteristics of these athletes might offer deeper insight into the variables and the specific training strategies that influence marathon performance.

Conclusions

Among U.S. Olympic Marathon Trials qualifiers, there is no consensus as to how to prepare for the marathon beyond running at a pace slower than race pace. Between performance levels, it seems that the specific year-round characteristics of training influence women's marathon performance more than men's, possibly as a result of the larger range of the women's performances.

Acknowledgments

This study was funded by the Counsilman Center for the Science of Swimming. In addition, the author would like to acknowledge Joel Stager, PhD, for his support and feedback on the manuscript; those who provided valuable feedback on the questionnaire; the men's marathon race director, Valerie McLean, for including the questionnaires in the athletes' race packets; USA Track & Field, for encouraging the athletes to participate in this study; Michael Caspar, for creating and posting the online version of the questionnaire (www.USurveys.com); and all of the athletes who participated in this study.

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