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Sex differences in performance-matched marathon runners

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Summary. Six male and six female runners were chosen on the basis of age (20-30 years) and their performance over the marathon distance (mean time = 199.4, SEM 2.3 min for men and 201.8, SEM 1.8 min for women). The purpose was to find possible sex differences in maximal aerobic power ($\dot{V}O_{2\,max}$), anaerobic threshold, running economy, degree and utilization of $\dot{V}O_{2\,max}$ (when running a marathon) and amount of training. The results showed that performance-matched male and female marathon runners had approximately the same $\dot{V}O_{2\,max}$ (about 60 $ml \cdot kg^{-1} \cdot min^{-1}$). For both sexes the anaerobic threshold was reached at an exercise intensity of about 83% of $\dot{V}O_{2\,max}$, or 88%-90% of maximal heart rate. The females' running economy was poorer, i.e. their oxygen uptake during running at a standard submaximal speed was higher ($P<0.05$). The heart rate, respiratory exchange ratio and blood lactate concentration also confirmed that a given running speed resulted in higher physiological strain for the females. The percentage utilization of $\dot{V}O_{2\,max}$ at the average marathon running speed was somewhat higher for the females, but the difference was not significant. For both sexes the oxygen uptake at average speed was 93%-94% of the oxygen uptake corresponding to the anaerobic threshold. Answers to a questionnaire showed that the females' training programme over the last 2 months prior to running the actual marathon comprised almost twice as many kilometres of running per week compared to the males (60 and 33 km, respectively). The better state of training of the females was also confirmed by a 10% higher $\dot{V}O_{2\,max}$ in relation to lean body mass than that of the male runners. Apart from the well-known variation in height and differences in the percentage of fat, the difference between performance-matched male and female marathon runners seemed primarily to be found in running economy and amount of training.

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Introduction

The rapidly increasing number of women participating in endurance sports, such as marathon running, has created a need for more knowledge about possible sex differences in the physiological response to prolonged physical exertion.

Intra-individual variations in running economy at a standard running speed have been shown by Costill et al. (1973) and Conley and Krahenbuhl (1980), among others. Studies of possible differences between the sexes as to how distance runners effect these economies are few. Furthermore, the interpretation of the results from such studies is often made difficult because the subjects have been at quite different performance levels (Drinkwater 1973; Daniels et al. 1977; Berg and Keul 1981).

The most logical method of studying possible sex differences in marathon runners is to compare performance-matched subjects of both sexes. The present investigation was, therefore, designed to study running economy, maximal aerobic power ($\dot{V}O_{2\,max}$), anaerobic threshold (Th_{an}) and the percentage utilization of $\dot{V}O_{2\,max}$ and Th_{an} during running in men and woman having equal performance ability over the marathon distance (about 3 h and 20 min). Also, the frequency, duration, intensity and type of training over the last 6 months prior to measurement were compared between the sexes.

Methods

Subjects. Six male and six female long-distance runners took part in the study. They were all informed about the practical implementation, risks and possible unpleasantness attached to the ex-

Table 1. Physical and physiological characteristics of the subjects

Variables	Men ($n=6$)		Women ($n=6$)	
	Mean	SEM	Mean	SEM
Age (years)	28	1.1	24	0.6
Mass (kg)	74.9	2.3	58.7	1.7
Height (cm)	181	1.3	166	1.5
% of fat[a]	8.7	0.9	19.4	0.4
$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)[b]	4.5	0.16	3.5	0.13
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)[b]	59.5	0.5	58.8	0.7
HR_{max} (beats $\cdot min^{-1}$)[b]	197	3.5	199	2.8
$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)[c]	4.6	0.16	3.6	0.13
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)[c]	61.5	0.6	60.0	0.9
HR_{max} (beats $\cdot min^{-1}$)[c]	198	3.4	201	3.1
Marathon performance time (min)	199.42	2.3	201.76	1.8

[a] Based on skin fold measurements (Sloan 1967; Sloan et al. 1962)
[b] Inclination of the treadmill 1° (1.75%)
[c] Inclination of the treadmill 3° (5.25%)
$\dot{V}O_{2max}$, Maximal aerobic power; HR_{max}, maximal heart rate

perimental protocol. The subjects' age, mass, height and percentage fat are given in Table 1.

In comparison with the female group the men were on average 4 years older, 16.2 kg heavier, 15 cm taller, had 1.05 $l \cdot min^{-1}$ higher $\dot{V}O_{2max}$ and had 10.7% less fat ($P<0.05$). There were, however, no statistically significant differences between women and men with regard to $\dot{V}O_{2max}$ in relation to mass ($ml \cdot kg^{-1} \cdot min^{-1}$), maximal heart rate ($HR_{max}$) or performance level over the marathon distance.

The athletic background and level of physical activity of the subjects were surveyed by the use of a questionnaire (Table 5).

Experimental procedure. Tests on a treadmill were carried out 7–14 days after the marathon, using the following procedure.
Day 1 (treadmill at 1° inclination): specification of Th_{an}; measurement of $\dot{V}O_{2max}$ and HR_{max}.
Day 2: Th_{an}; 45-min break; average speed of marathon (v_M); $\dot{V}O_{2max}$ and HR_{max} (treadmill at 3° inclination).
There was at least 1 rest-day between the two test-days.

The procedure for measuring $\dot{V}O_{2max}$ was as follows. The speed of the treadmill was increased to a level which, during preliminary tests, brought the subject close to exhaustion after about 3 min. The expired air was collected in two Douglas bags from the 2nd to the 3rd min of running and analysed using a paramagnetic Beckman model 755 oxygen analyser and a Beckman model 864 infra-red CO_2 analyser (Beckman Instruments, Fullerton, Calif., USA). The volume of air in the Douglas bags was measured using a Wilhelm Ritter KG (Kunststoff-Werkstätten, Bochum-Rangendreer, FRG) wet gas meter (Ingjer 1979).Telemetering equipment was used for measuring HR. Immediately after the procedure for measuring $\dot{V}O_{2max}$, the subjects ran for 2 min at an exercise intensity of about 60% of $\dot{V}O_{2max}$, directly followed by a supra-maximal intensity, resulting in exhaustion after about 3 min. The highest HR during the last minute was used as HR_{max}.

To determine Th_{an} the following protocol was used. After warming up for about 10 min at an exercise intensity of about 50% $\dot{V}O_{2max}$, the subjects ran for 5 min at each of five different speeds (representing exercise intensities ranging from 60% to 95% $\dot{V}O_{2max}$), with a 30 s pause for the determination of blood lactate concentration ([la_b]). HR was recorded over the last 2 min at each intensity and the average value was used. The expired air was collected in Douglas bags over 4–4.5 min at every intensity. The speed of the treadmill was increased in steps of 20 $m \cdot min^{-1}$, and all the measurements were carried out at 1° inclination to compensate for the air resistance which occurs when running outdoors (Heck et al. 1982).

In order to use the data obtained from the above-described protocol for Th_{an} determination, a preliminary study was undertaken. Thus, values for running speed, HR, oxygen uptake ($\dot{V}O_2$), and [la_b] were recorded during a series of running sessions. Each test was performed at constant speed over a period of 20 min, and on separate days. The highest exercise intensity measured as running speed, $\dot{V}O_2$ or HR during the constant speed tests, where the [la_b] increased only slightly during the last 15 min (<1 mM) was then defined as Th_{an}. The values from the constant speed tests were then compared to the values from the graded tests. From the results of these studies, it was concluded that Th_{an}, using the graded protocol, was reached at a $\dot{V}O_2$ which gave on average [la_b] 1.5 mM (ranging from 1.3 to 1.7 mM) higher than those found immediately after the warming-up period. To determine [la_b], blood samples were taken from a fingertip and analysed by a Roche Model 640 lactate analyser (Roche Bio-electronics, Hoffmann-La Roche, Basel, Switzerland) (Soutter et al. 1978).

From each subject's actual time of running in the marathon, the v_M was calculated (Costill and Fox 1969). After warming-up for 10 min at a running speed 75% of v_M, the treadmill speed was then increased to v_M and kept there for 11 min.

The average value of the $\dot{V}O_2$ after 5.25 and 10.25 min was used. The HR was recorded every 15 s, and the average value for the periods 3–4, 6–7 and 9–10 min was determined. Blood samples for determining the [la_b] were taken during continuous running. The average value for these measurements at 7.5 and 10 min gave [la_b] at v_M.

Statistical analysis. Wilcoxon's test for paired data was used when the same group of subjects was compared at different times. Wilcoxon (Mann-Whitney) tests for samples of two groups were used when men and women were compared. A combined probabilities test was used to compare the within-group results of the five running speeds simultaneously (Fischer 1954). As a measure of dispersal of average values, the standard error of mean (SEM) was used. The calculation of graph adjustments was based on the least-squares method. A level of significance on 5% ($P<0.05$) was regarded as statistically valid.

Results

The $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$) was on average 3% higher when running on the treadmill at 3° inclination, compared to the value reached at 1° inclination, both for men and for women ($P<0.05$). There were, however, no statistically significant differences in $\dot{V}O_{2max}$ expressed in $ml \cdot kg^{-1} \cdot min^{-1}$ for the two groups, at either 1° or 3° inclination. Related to lean body mass ($m_{b,l}$), the women had, however, on average, approximately 8 $ml \cdot kg$ $m_{b,l}^{-1} \cdot min^{-1}$ higher $\dot{V}O_{2max}$ at both treadmill inclinations ($P<0.01$).

The HR_{max} at 1° and 3° inclinations of the treadmill was approximately equal for the two sexes (about 200 beats $\cdot min^{-1}$), and there were no statistical differences between the groups.

The results from the submaximal test are shown in Table 2. Figure 1 shows that the women were characterized by 3%–6% higher $\dot{V}O_2$ when running at standardized sub-maximal speeds (60%–95% $\dot{V}O_{2max}$) ($P<0.05$). They had higher HR ($P<0.01$), [la_b] (Fig. 2, $P<0.05$) and respiratory exchange ratio (R) ($P<0.05$). If, however, the [la_b] and R were expressed as functions

Table 2. Results from the submaximal test (treadmill at 1° inclination)

Sex	Running speed	$\dot{V}O_2$ (STPD)						HR (beats·min^{-1})		HR (% max)		$\dot{V}_E$ (BTPS) (l·min^{-1})		R		[la$_b$] (mM)	
	(m·min^{-1})	(l·min^{-1})		(ml·kg^{-1}·min^{-1})		(% $\dot{V}O_{2max}$)											
		Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Male (n=6)	140	2.35	0.12**	31.4	0.9	52.4	0.9	130.0	6.0	66.0	2.1	53.5	2.9	0.86	0.02	0.94	0.12
	180	2.81	0.08***	37.7	0.6*	62.9	0.7*	144.0	5.2*	73.0	1.6*	62.0	2.3	0.85	0.01	0.95	0.12
	200	3.13	0.09***	42.0	0.8	70.2	1.1	154.0	4.7*	78.2	1.4*	69.4	1.8	0.86	0.01	1.10	0.13
	220	3.48	0.10***	46.7	0.5	78.0	0.9	165.0	4.6	83.5	1.3*	81.9	4.2	0.89	0.02	1.60	0.21
	240	3.79	0.08***	50.8	0.7	84.9	1.4	175.0	4.2	88.7	0.8**	99.2	2.9	0.93	0.01	2.71	0.37*
	260	4.07	0.12***	54.6	0.4	91.3	1.1	183.0	4.6	92.8	1.0	113.4	7.6	0.95	0.02*	5.20	0.58*
Female (n=6)	140	1.91	0.07	32.5	0.7	55.3	1.4	141.0	2.6	70.9	1.5	44.7	4.6	0.83	0.02	0.89	0.07
	180	2.35	0.09	40.1	1.2	68.3	2.4	157.0	2.3	78.7	1.4	57.7	5.1	0.86	0.02	1.11	0.14
	200	2.56	0.06	43.7	0.9	74.3	2.0	167.0	2.9	83.8	1.7	64.5	4.8	0.87	0.01	1.31	0.18
	220	2.81	0.07	48.0	0.9	81.7	1.9	176.0	2.9	88.5	1.6	76.6	6.2	0.91	0.01	2.12	0.32
	240	3.06	0.07	52.2	0.7	88.9	1.7	185.0	3.2	93.2	1.4	89.9	5.6	0.95	0.01	4.13	0.62
	260	3.29	0.09	56.0	0.7	95.3	1.2	194.0	2.9	97.3	1.0	107.8	3.5	1.00	0.02	7.41	0.80

Levels of significance: * $P<0.05$; ** $P<0.01$; *** $P<0.001$; STPD, standard temperature and pressure, dry; BTPS, body temperature and pressure, saturated; $\dot{V}O_2$, oxygen uptake; $\dot{V}O_{2max}$, maximal aerobic power; HR, heart rate; $\dot{V}_E$, expired minute ventilation; R, respiratory exchange ratio; [la$_b$], blood lactate concentration

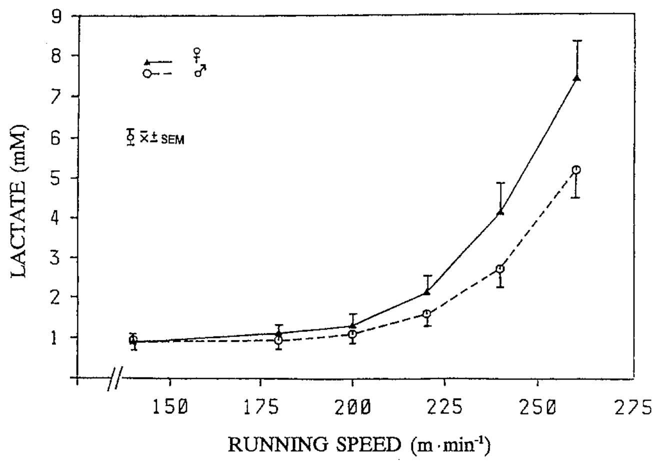

Fig. 1. Average oxygen uptake in relation to running speed (treadmill at 1° inclination); the equations were derived from linear regressions

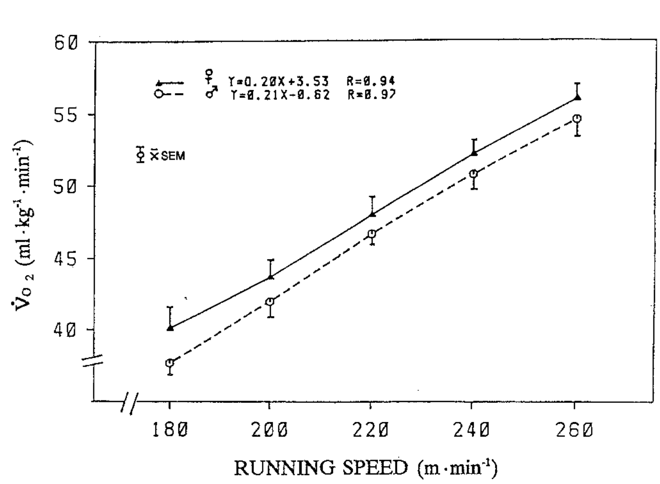

Fig. 2. Average blood lactate concentration in relation to running speed (treadmill at 1° inclination)

of % $\dot{V}O_{2max}$, there were no significant differences between the sexes.

Physiological parameters at Th$_{an}$ for the two groups appear in Table 3. The Th$_{an}$ was for both groups about 83% and 88%–89% HR$_{max}$.

At v_M the percentage utilization of $\dot{V}O_{2max}$ was for both sexes about 78% (Table 4). Table 4 also shows that $\dot{V}O_2$ at v_M was 93%–94% of Th$_{an}$.

Table 5 gives some of the results from the questionnaire for both sexes. The table shows that the women trained far more than the men. Each week during the last 2 months before the marathon, the women trained 1.8 days ($P<0.05$), 2.4 h ($P<0.05$) and 27 km ($P<0.05$) more than the men. There were no major differences between the groups as far as the number of high-intensity workouts was concerned.

Discussion

The Th$_{an}$ marks the upper limit for predominantly aerobic metabolism. As seen in Table 3, Th$_{an}$ on an average,

Table 3. Physiological parameters at anaerobic threshold determined from the submaximal test (Table 2); mean and SEM

Sex	$v_{Th_{an}}$ $(m \cdot min^{-1})$		$\dot{V}O_2$ (STPD) $(l \cdot min^{-1})$		$(ml \cdot kg^{-1} \cdot min^{-1})$		$(\% \dot{V}O_{2max})$		HR $(beats \cdot min^{-1})$		HR (% max)		$\dot{V}_E$ (BTPS) $(l \cdot min^{-1})$		R		$[la_b]$ (mM)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Male ($n=6$)	236	3.6	3.73	0.12	49.9	1.0	83.2	1.8	173	3.8	87.9	0.6*	94.6	1.5*	0.92	0.01	2.44	0.12
Female ($n=6$)	225	4.6	2.89	0.10	49.2	0.5	83.6	0.9	179	2.4	89.7	0.7	81.1	5.7	0.91	0.01	2.39	0.07

Level of significance: * $P<0.05$; for definitions see Table 2

Table 4. Physiological parameters at v_M; mean and SEM

Sex	v_M $(m \cdot min^{-1})$		$\dot{V}O_2$ (STPD) $(l \cdot min^{-1})$		$(ml \cdot kg^{-1} \cdot min^{-1})$		$(\% \dot{V}O_{2max})$		HR $(beats \cdot min^{-1})$		HR (% max)		$\dot{V}_E$ (BTPS) $(l \cdot min^{-1})$		R		$[la_b]$ (mM)		$\frac{\dot{V}O_2 \text{ at } v_M \cdot 100}{\dot{V}O_2 \text{ at } Th_{an}}$ (%)	
	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM	Mean	SEM
Male ($n=6$)	212	2.4	3.46	0.13***	46.3	0.6	77.4	1.3	166	3.6	84.3	0.8*	82.6	3.4	0.89	0.02	1.52	0.16	92.9	2.5
Female ($n=6$)	209	2.0	2.72	0.08	46.5	1.1	78.8	1.4	175	2.6	88.1	0.9	70.9	5.8	0.87	0.01	1.61	0.10	94.3	1.2

Levels of significance: * $P<0.05$; ** $P<0.01$; *** $P<0.001$; Th_{an}, anaerobic threshold; for other definitions see Table 2

Table 5. Athletic background and amount of training over the last 6 months; mean and SEM

Variable	Male ($n=6$)		Female ($n=6$)	
	Mean	SEM	Mean	SEM
Athletic background				
endurance training (years)	6.3	1.7	5.7	1.4
competitive sport (years)	5.3	1.8*	9.5	1.4
race running (years)	3.3	0.4	4.3	1.6
number of completed marathon races	2.7	0.3	2.0	0.5
Weekly endurance training over the last 6 months				
days	3.1	0.6**	5.0	0.3
hours	3.3	0.6**	6.6	0.5
high-intensity work-outs (n)	0.8	0.2	1.3	0.3
Weekly running over the last 6 months				
First 4 months:				
days	2.4	0.3	2.9	0.8
hours	2.3	0.3	3.2	1.1
% of total endurance training	69.7	8.4	48.5	14.6
kilometres	24.0	3.0	33.0	12.3
high intensity work-outs (n)	0.8	0.2	1.1	0.7
Last 2 months:				
days	2.9	0.5*	4.7	0.7
hours	3.3	0.6*	5.6	0.8
% of total endurance training	100.0	13.7	84.8	12.7
kilometres	33.0	5.1*	60.0	9.8
high intensity work-outs (n)	0.9	0.2	1.2	0.4

Levels of significance: * $P<0.05$; ** $P<0.01$

lies at $\dot{V}O_2$ of about 50 $ml \cdot kg^{-1} \cdot min^{-1}$ (or about 83% $\dot{V}O_{2max}$) for both men and women. The threshold value based on fixed [la_b], e.g. 2 or 4 mM, also does not indicate any sex differences (Table 2). It has not been possible to find any comparative studies of Th_{an}, where the starting point has been equal age and level of performance for the two sexes. The Th_{an} seems to represent an approximately identical exercise intensity for each sex (Table 3). This was also confirmed by the insignificant differences in HR and R at Th_{an}. Even though the average speed at Th_{an} was about 10 $m \cdot min^{-1}$ higher for men, the differences were not statistically significant. A reasonable explanation for the non-significant difference in running speed at Th_{an} might be found in the poorer running economy of the women. Running economy is commonly defined as the steady-state $\dot{V}O_2$, (in $ml \cdot kg^{-1} \cdot min^{-1}$) at a standard speed (Costill et al. 1973; Conley and Krahenbuhl 1980). The variations in running economy between the sexes in the present study were about 4–5 $ml \cdot kg^{-1} \cdot min^{-1}$ at all submaximal running speeds (Table 2). This is in accordance with previous studies of corresponding groups (Costill and Fox 1969; Bransford and Howley 1977). Even though Costill et al. (1973) have claimed that the variations in economy are occasional, they have shown that marathon runners have the lowest $\dot{V}O_2$ at all speeds used in their investigation. As shown (Table 2, Fig. 1) the women had $\dot{V}O_2$ about 1.6 $ml \cdot kg^{-1} \cdot min^{-1}$ higher during submaximal running than the men at the same speed. Corresponding observations have been reported by Daniels et al. (1977), Cureton and Sparling (1980) and Pate et al. (1985), even though the differences did not reach statistical significance. Equal $\dot{V}O_2$ (Table 1) indicates that the women's higher percentage of fat cannot per se explain the sex differences in running economy. However, women have more fat around their hips and thighs than men (Wilmore et al. 1977). This might lead to an additional weight stress for each stride, so that submaximal $\dot{V}O_2$ thereby becomes higher.

It has been suggested that the female physique is less suited for running than the male. Width of hips, length of bones and stride have all been mentioned as possible mechanical disadvantages for women (Stanley and Brubaker 1973; Dillman 1975; Nelson et al. 1977). The measurements of HR, R and [la_b] also confirm that a given speed represents a higher stress for women (Table 2, Fig. 2). If, however, these parameters are presented as a function of relative exercise intensity (% $\dot{V}O_{2max}$), there are no differences between men and women. Thus, these measurements reflect the poorer running economy of the women.

In both men and women $\dot{V}O_2$ at v_M was about 78% (73%–84%) of $\dot{V}O_{2max}$ and 93%–94% of $\dot{V}O_2$ at Th_{an}. As seen in Table 4, there was a tendency for a somewhat higher degree of utilization in the females. However, the difference was not significant. Davies and Thompson (1979) have found that at v_M men utilized about 82% (80%–87%) and women utilized about 79% (68%–86%) of $\dot{V}O_{2max}$. A field study of Maron et al. (1976) showed that $\dot{V}O_2$ for well-trained men varied between 68% and 100% of $\dot{V}O_{2max}$ during a marathon, depending on speed and terrain. The average running intensity was, on the other hand, equal to about 75% $\dot{V}O_{2max}$. With the exception of this field study, other studies are based on measurements on a horizontal treadmill. This results in an under-estimation of the degree of utilization (Heck et al. 1982). In addition, the above-mentioned studies were related to $\dot{V}O_{2max}$ at 3° uphill or more, in contrast to the present study where 1° inclination was used.

The [la_b] at v_M was approximately equal for the two sexes (Table 4), the values lying between 1 and 2 mM. Costill (1970) and Farrell et al. (1979) have found equivalent values after marathons.

During a marathon, fat gradually becomes an important substrate for re-synthesis of ATP. On the other hand, a number of studies have shown that lipolysis is inhibited by metabolic acidosis (Hjemdahl and Fredholm 1974; Issekutz et al. 1975). On the basis of [la_b] at v_M in the present study, one should, therefore, not expect any special inhibition of the lipolysis during races. Some have claimed that women have a higher capacity for oxidization of fat than men (glycogen saving, Komi and Karlsson 1979; Jansson 1980). A study of well-trained runners, however, did not add any support to a possible sex difference where metabolism of fat is concerned (Costill et al. 1979); nor do the R or $[la_b]$ values at v_M in the present study support such a theory.

When trying to distinguish biological differences from the behavioural ones, it is important to know the subject's intensity of training and its amount. The results from the questionnaires showed that the subjects were a relatively homogeneous group in respect of the type of training. The training programme consisted mainly of continuous submaximal exercise with a relatively small element of more intensive training (e.g. interval-training, Table 5). The main finding from the questionnaires was that the women trained far more than the men. During the 6-month period prior to competition and especially during the last 2 months, which represents specialization towards marathon running, the women ran on an average almost twice as far per week, 60 km and 33 km for women and men respectively. Sjødin and Jacobs (1981) have found a strong relationship between v_M and the number of kilometres run each week over the last 2 months before the marathon ($r = 0.94$, $P < 0.001$). Their study was, however, based on a very heterogeneous group of men.

As shown in Table 1, $\dot{V}O_{2\max}$ for men and women at an equal level of performance was practically the same (about 60 $ml \cdot kg^{-1} \cdot min^{-1}$) and not unexpectedly about 3% higer at 3° inclination than at 1°. Pate et al. (1985), comparing men and women having equal performance ability over a 24-km run, also found no differences in aerobic power between the sexes. However, when comparing men and women, $\dot{V}O_{2\max}$ expressed as $ml \cdot kg\ m_{b,l}^{-1} \cdot min^{-1}$ is a better measure of the state of endurance training: the higher values of the women indicate that they were better trained than the men. This was also corroborated in the questionnaire (Table 5). Since the level of achievement in marathons was approximately equal for both sexes, the womens' extra mass in fat obviously limited their physical performance in activities where the mass of the body was critical, e.g. running.

Both women and men had an average HR_{max} of about 200 $beats \cdot min^{-1}$ (Table 1). This is in agreement with other investigations, which have concluded that there is no difference between sexes with regard to HR_{max} (e.g. Cureton and Sparling 1980; Pate et al. 1985).

Conclusion

A comparison of performance-matched female and male marathon runners (completing the marathon distance in about 3 h 20 min) showed that they have approximately identical $\dot{V}O_{2\max}$, HR_{max} and Th_{an} (expressed as % of $\dot{V}O_{2\max}$). However, they differ with respect to running economy, which is poorer for the females, and the quantity of training, the females running almost twice as far per week over the last 2 months prior to the marathon. The poorer running economy may have been compensated by the tendency to a higher utilization of $\dot{V}O_{2\max}$ (or % $\dot{V}O_{2\max}$ at v_M), although the difference was not significant. A higher utilization level in the females would be expected on the basis of their more extensive endurance training prior to the marathon.

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