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Significance of the contribution of aerobic and anaerobic components to several distance running performances in female athletes

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Summary. To assess the most important determinant for successful distance running (800 m, 1500 m and 3000 m events) in female athletes, measurements of several anaerobic indices were made (peak power, mean power) using the Wingate anaerobic test (WAnT), and aerobic indices such as oxygen uptake ($\dot{V}_{O_2}$) or running velocity (v) at lactate threshold (LT), $\dot{V}_{O_2}$ or v at onset of blood lactate accumulation (OBLA), running economy (RE), and maximal oxygen uptake were determined using the incremental treadmill test. The RE was represented by a $\dot{V}_{O_2}$ value measured at 240 $m \cdot min^{-1}$ of a standard treadmill velocity. A stepwise multiple regression analysis (SAS stepwise procedure) combined the best features of forward inclusion and backward elimination to determine the most important factors in predicting the performance of running these distances as dependent variables. The stepwise procedure showed that the blood lactate variables such as LT and/or OBLA are highly correlated with, and contributed to predicting performance running 800 m-3000 m, whereas the anaerobic component was related only to running 800 m. In conclusion, blood lactate variables account for a large part of the variation in distance running performance in female as in male runners. The component of the anaerobic system which can be measured by the WAnT was shown to contribute to performance in running 800 m, but not in longer distances.

Key words: Blood lactate variables - Female distance runners - Wingate anaerobic test

Introduction

Recently, the number of female distance runners and their opportunity to compete in the long-distance race have increased. In male distance runners, numerous studies have found that blood lactate variables such as lactate threshold (LT) or onset of blood lactate accumulation (OBLA) account for a large part of the variation in endurance performance. Specifically, cross-sectional and/or longitudinal studies have shown that endurance training results in the decrease of lactate concentration in muscle and blood during submaximal exercise. In fact, blood lactate variables rather than maximal oxygen uptake ($\dot{V}_{O_{2max}}$) are highly correlated with endurance performance in male endurance athletes (Allen et al. 1985; Farrell et al. 1979; Holloszy et al. 1977; Jacobs 1986; Kumagai et al. 1983; Tanaka and Matsuura 1984; Tanaka et al. 1984, 1985; Williams and Nute 1983).

According to the recent paper by Pate et al. (1987), which compared elite with non-elite female distance runners, $\dot{V}_{O_{2max}}$ is significantly higher, the values of oxygen uptake ($\dot{V}_{O_2}$), ventilation and heart rate at a given running velocity (v) are significantly lower, while the muscles of female distance runners appeared to show a remarkable similarity in fibre composition and enzymatic activity to male distance runners except for the fibre areas (Costill et al. 1976a, b, 1987). Less attention has been paid to the importance of blood lactate variables in running in female athletes (Daniels et al. 1986; Yoshida et al. 1989a).

In addition, few data are available for assessing the contribution of aerobic and anaerobic components to success in the distance events. For example, the anaerobic contribution to distance running may depend on the homogeneity of subjects (Bulbulian et al. 1986), on the racing tactics, or on the distance run.

The purpose of this study is to examine the proposition that for female distance runners also the contribution of blood lactate variables might be critical in predicting distance running performance. In addition, the contributions of the anaerobic components, running economy (RE) and $\dot{V}_{O_{2max}}$ were also assessed with regard to distance running performance.

Methods

Subjects. Sixteen female distance runners volunteered to be subjects for the present study. They competed primarily in races up to

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5000 m and were successful at the collegiate level. Their average age, height, mass, and finishing times for running 800 m, 1500 m, and 3000 m were 19.1 years, SD 1.0, 160.3 cm, SD 4.5, 50.1 kg, SD 6.3, 2.29 min, SD 0.07, 4.80 min, SD 0.19, 10.32 min, SD 0.32, respectively. After being informed of the purpose, benefits and possible risks of the present study, they gave written consent to serve as subjects.

Wingate anaerobic test. The Wingate anaerobic test (WAnT) was performed using a Monark cycle ergometer (Monark-Crescent, Varburg, Sweden), on which the seat height was adjusted to allow for full extension of the legs. Each subject was secured to the pedals with toe clips and straps. After an appropriate warm-up, the subject began to pedal as fast as possible, while the resistance was quickly adjusted to the nearest 0.5 Kp setting corresponding to 10% of the subject's body mass according to the method proposed by Bar-Or (1987). During the following 30 s, the subject was urged to pedal as fast as possible. A photocell was used to count the total revolutions of the flywheel of the ergometer and its output was transferred into a computer via an analog/digital conversion. Peak power (PP) was the highest work output during any 5-s interval of the test and was assumed to reflect the ability of the limb muscles to produce high mechanical power in a short time (Bar-Or 1987). Mean power (MP), on the other hand, was calculated as the total work done during the 30-s test period and was assumed to reflect the ability of the limb musculature to sustain extremely high power (Bar-Or 1987).

The gas exchanges both during and in the recovery from WAnT exercise were measured with a computerized on-line breath-by-breath system (RM-300, Minato Medical Science, Osaka, Japan). Inspired and expired flows were measured using a hot-wire respiratory flow system. The concentrations of O_2 and CO_2 were analysed, with a zirconia solid electrolyte O_2 analyser and infra-red CO_2 analyser (MG-360, Torey, Osaka, Japan), respectively. The output from the breath-by-breath instrument was transferred into the computer via a RS-232C port for further analysis. Oxygen debt was calculated as excess recovery $\dot{V}_{O_2}$ above the resting level.

Incremental treadmill exercise test. To determine LT, OBLA, RE, and $\dot{V}_{O_{2max}}$, the subject performed an incremental treadmill exercise test. The test consisted of an initial velocity of 180 $m \cdot min^{-1}$ for 5 min on the level, and then the velocity was increased 20 $m \cdot min^{-1}$ every 5 min until the subject reached voluntary exhaustion. During the treadmill test, gas exchange parameters were determined by the breath-by-breath method as above. The RE was defined as the $\dot{V}_{O_2}$ at $v = 240$ $m \cdot min^{-1}$, as described by Powers et al. (1983) and Bulbulian et al. (1986). The criteria for obtaining $\dot{V}_{O_{2max}}$ included both a levelling-off of $\dot{V}_{O_2}$ as v increased and a respiratory exchange ratio at exhaustion greater than 1.15.

Arterialized capillary blood was taken from the ear-lobe immediately after each v of the treadmill test. Blood lactate was analysed by an enzymatic membrane method (Diagluca HEK-30L, Toyobo, Osaka, Japan), which had been calibrated against a standard concentration of lactate solution.

Determination of LT and OBLA. Two different indices for blood lactate accumulation during exercise, LT and OBLA, were selected and used for evaluating endurance ability. The LT was defined as the point ($\dot{V}_{O_2}$ or v in the present study) at which the blood lactate concentration began to increase above a resting level (Yoshida et al. 1987). To identify the LT, a log-log transformation of the relationship between blood lactate and v or $\dot{V}_{O_2}$ during the submaximal exercise tests was used according to the procedures described by Beaver et al. (1986). The OBLA was defined as the v or $\dot{V}_{O_2}$ at which the blood lactate concentration reached a value of 4 mM (Karlsson et al. 1984). The log-log transformation was also used to determine v at OBLA or $\dot{V}_{O_2}$ at OBLA.

Running performance test. The 800 m, 1500 m, 3000 m finishing times were selected from performances in competitive running recorded on a racing track within 2 weeks of the laboratory experiments. They were converted into velocities for the purpose of analysis.

Statistical analyses. A stepwise multiple regression model was employed to predict distance running performances as dependent variables. The data for PP and MP during WAnT, $\dot{V}_{O_2}$ at LT, v at LT, $\dot{V}_{O_2}$ at OBLA, v at OBLA, RE, and $\dot{V}_{O_{2max}}$ were entered into the stepwise procedure (SAS STEPWISE). This stepwise multiple regression technique combined the best features of forward inclusion and backward elimination to determine the most important factors in predicting the dependent variable as each distance running performance. The $P < 0.05$ level of significance was accepted for all correlations.

Results

Table 1 shows the data obtained from the tests in the present study. It is apparent that the subjects in the present study are relatively homogeneous with regard to their performance, having coefficients of variance (CV) which range from 3.1% to 4.7%. This contrasts with the CV values for PP, $PP \cdot kg^{-1}$, MP and $MP \cdot kg^{-1}$, which range as high as 20.9%. The data for PP, $PP \cdot kg^{-1}$, MP and $MP \cdot kg^{-1}$ in the present study are comparable to those reported elsewhere (Bar-Or 1987), while the values of RE, LT, OBLA and $\dot{V}_{O_{2max}}$ are similar to data obtained in our previous experiments (Yoshida et al. 1989b).

Table 2 shows single correlation coefficients between selected physiological data and the dependent variables of running velocity over 800 m, 1500 m and 3000 m. Over 800 m significant coefficients were obtained in relation to PP, MP, $\dot{V}_{O_2}$ at LT, $\dot{V}_{O_2}$ at OBLA, and v at OBLA. For 1500 m, $\dot{V}_{O_2}$ at LT, v at LT, $\dot{V}_{O_2}$ at OBLA, and v at OBLA were significantly correlated

Table 1. Data obtained in the present study

Variables	Mean	SD	CV (%)
Peak power (W)	438.1	89.1	20.3
Peak power per kg ($W \cdot kg^{-1}$)	8.8	1.2	13.1
Mean power (W)	346.7	72.7	20.9
Mean power per kg ($W \cdot kg^{-1}$)	6.9	1.0	14.2
Running economy ($ml \cdot kg^{-1} \cdot min^{-1}$)	48.1	2.8	5.8
v at LT ($m \cdot min^{-1}$)	213.8	14.1	6.6
$\dot{V}_{O_2}$ at LT ($ml \cdot kg^{-1} \cdot min^{-1}$)	43.3	4.1	9.5
v at OBLA ($m \cdot min^{-1}$)	268.6	30.0	11.2
$\dot{V}_{O_2}$ at OBLA ($ml \cdot kg^{-1} \cdot min^{-1}$)	52.9	4.0	7.6
$\dot{V}_{O_{2max}}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	56.4	4.4	7.8
O_2 debt ($ml \cdot kg^{-1}$)	50.7	7.1	13.9
800 m ($m \cdot min^{-1}$)	347.9	10.7	3.1
1500 m ($m \cdot min^{-1}$)	312.9	10.9	3.5
3000 m ($m \cdot min^{-1}$)	292.7	13.7	4.7

CV = Coefficient of variance

Table 2. Single correlation coefficients between the selected parameters and running velocity

Running velocity ($m \cdot min^{-1}$)	800 m	1500 m	3000 m
Peak power (W)	0.59*	0.31	0.11
Peak power per kg ($W \cdot kg^{-1}$)	0.27	0.05	0.24
Mean power (W)	0.54*	0.26	0.15
Mean power per kg ($W \cdot kg^{-1}$)	0.24	0.01	0.25
Running economy ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.13	0.34	0.23
v at LT ($m \cdot min^{-1}$)	0.43	0.65**	0.70**
$\dot{V}_{O_2}$ at LT ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.77**	0.66**	0.64**
v at OBLA ($m \cdot min^{-1}$)	0.68**	0.85**	0.88**
$\dot{V}_{O_2}$ at OBLA ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.51*	0.55*	0.69**
$\dot{V}_{O_{2max}}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.44	0.45	0.67**

* $P<0.05$, ** $P<0.01$

with v. For 3000 m, $\dot{V}_{O_2}$ at LT, v at LT, $\dot{V}_{O_2}$ at OBLA, v at OBLA, and $\dot{V}_{O_{2max}}$ were significantly correlated with v. It is of interest that the lactate variables LT and OBLA are strongly related to all distance v studied in the present experiment.

Table 3 provides data from a stepwise multiple regression analysis which selects the best contributor for predicting v in regression using the data from 800 m, 1500 m and 3000 m races as dependent variables (Table 3). In the case of 800 m races, the combination of $\dot{V}_{O_2}$ at LT and MP as independent variables accounted for 73.0% of total variance necessary to predict v. In the case of 1500 m races, the combination of v at OBLA and $\dot{V}_{O_{2max}}$ as independent variables accounted for 79.6% of the total variance. Finally, in 3000 m races, the combination of v at OBLA and $\dot{V}_{O_2}$ at OBLA as independent variables accounted for 86.4% of the total variance. As shown in Table 3, the blood lactate variables, such as v at LT and v at OBLA, were selected as the best predictors.

Discussion

The two principal concerns of the present study were to establish the significance of blood lactate variables for distance running in female runners, and to predict the distance v using a purely statistical approach, combining blood lactate variables with other important parameters such as PP, MP, RE, or $\dot{V}_{O_{2max}}$. To assess the validity and the predictive value for the field and laboratory indices of both aerobic and anaerobic performance, various physiological variables, which might be strongly related to distance running, were incorporated in a stepwise multiple regression procedure.

The main findings of the present study were that:

1. A stepwise procedure suggested the significant contribution of blood lactate variables combined with other physiological parameters in predicting v over 800 m, 1500 m and 3000 m in female distance runners.
2. The anaerobic component obtained by WAnT is related to v only over 800 m.

It has been well documented that the muscle fibre composition and enzymatic activity in female distance runners are remarkably similar to those of male distance runners (Costill et al. 1976a, b, 1987). Furthermore, since endurance training induces adaptations in muscle cells which result in a reduced production of lactate during heavy exercise (Hurley et al. 1984; Favier et al. 1986), it is assumed that in female distance runners also blood lactate variables may play a critical role, as has been established for male distance runners. In female distance runners, Pate et al. (1987) described how in "elite" runners blood lactate concentration is lower at a standard treadmill velocity than that in "good" runners, suggesting that blood lactate response to submaximal exercise is a very sensitive discriminator of competitive status. However, their study did not identify the importance of blood lactate variables such as LT and OBLA for distance running in females. In the present study, it has been demonstrated that there is a significant relationship between blood lactate variables and running in females. This finding is consistent with the statistical results obtained in earlier studies on male elite athletes, which indicated the importance of blood lactate variables for male athletes in achieving success in distance running (Allen et al. 1985; Farrell et al. 1979; Kumagai et al. 1983; Tanaka et al. 1984, 1985; Williams and Nute 1983). Furthermore, using untrained female subjects, Yoshida (1986) and Yoshida et al. (1987) have suggested that lactate variables may be more useful indices for endurance performance than other variables such as $\dot{V}_{O_{2max}}$, step test score, and predicted physical work capacity at a heart rate of 170 $beats \cdot min^{-1}$. Hence, in female distance runners also, it

Table 3. Stepwise multiple regression analysis for the selected variable and highest velocity in 800 m, 1500 m and 3000 m running for female athletes

Step number	800 m running velocity			1500 m running velocity			3000 m running velocity		
	Variables	multiple r^2	$\Delta r2$	Variables	multiple r^2	Δr^2	Variables	multiple r^2	Δr^2
1	v at LT	0.6	$P<0.01$	v at LT	0.73	$P<0.01$	v at OBLA	0.77	$P<0.01$
2	MP	0.73	$P<0.05$	$\dot{V}_{O_{2max}}$	0.80	$P<0.05$	$\dot{V}_{O_2}$ at OBLA	0.86	$P<0.01$
3	RE	0.75	ns	v at OBLA	0.81	ns	RE	0.89	ns

v = Running velocity; LT = lactate threshold; MP = mean power; RE = running economy; $\dot{V}_{O_{2max}}$ = maximal oxygen uptake; OBLA = onset of blood lactate accumulation; ns = no significance

is not surprising to note that blood lactate variables account for a significant portion of the total variance (73%–86%) in distance running. On the other hand, a significant correlation between $\dot{V}_{O_2max}$ and v was only found over 3000 m (Table 2).

It is interesting to note that v over 800 m correlates with both such blood lactate variables as aerobic components and anaerobic components, such as PP and MP. In the case of the 800 m, there might be a distinct predominance of aerobic and lactic systems in the supply of ATP energy. The key point is the extent to which these systems contribute towards good performance over 800 m. A stepwise procedure selected $\dot{V}_{O_2}$ at LT as a first predictor ($r^2 = 0.60$). As a second prediction, the stepwise procedure chose MP, which is assumed to reflect the endurance of leg muscles (Bar-Or 1987). In other words, MP may be considered to reflect the ability to sustain extremely high power. Since one of the major contributors of energy towards good 800 m performance is derived from the rate of anaerobic glycolysis in the muscle and the ability to endure it, it is reasonable to consider that MP which can be measured in WAnT might be one of the effective discriminators for success.

On the other hand, performance at other longer distances was not significantly related to any anaerobic component (see Table 2). This observation does not agree with the data by Bulbulian et al. (1986). They observed that anaerobic work capacity accounts for 58% of the total variance together with $\dot{V}_{O_2max}$, and suggested a significant contribution of anaerobic capacity to performance over 8.05 km in a highly homogeneous group of aerobic factors ($\dot{V}_{O_2max}$, anaerobic threshold, RE). Although anaerobic components during distance running may play a practical role in changing the race pace and/or the finishing order of the race, the present study suggests that such anaerobic components are not significant determinants of performance over longer distances.

It has been suggested that the RE in female runners is indeed less than in males due to sex-linked anatomical differences, e.g. the wider pelvis, shorter legs and more oblique femur of the female, may contribute to a lesser mechanical efficiency of running (Stanley and Brubaker 1973). However, Daniels et al. (1977) found no significant difference between male and female distance runners in RE. The values of RE and $\dot{V}_{O_2max}$ obtained in the present study do not significantly differ from the values reported by Daniels et al. (1977). In fact, in the present study, RE was not correlated with performane in a simple regression analysis (Table 2) nor did it improve the level of significance for the prediction by a multiple regression analysis (Table 3). This observation, based on a simple regression analysis, is in agreement with the data obtained by Farrell et al. (1979), Conley et al. (1981) and Powers et al. (1983). These authors suggested that using subjects who are relatively homogeneous in both performance and RE, the correlation between the two is relatively low. In the present study the CV values indicate that the subjects are relatively homogeneous in performance, RE and $\dot{V}_{O_2max}$ (Table 1). Thus, rather than RE, blood lactate variables appear to make a more significant contribution to success in distance running in female athletes.

In conclusion, in female distance runners as in their male counterparts the blood lactate variables account for a large part of the variation in distance running. The component of the anaerobic system which was measured by WAnT was shown to contribute to performance over 800 m, but not over longer distances.

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References

Allen WK, Seals DR, Hurley B, Ehsani AA, Hagberg JM (1985) Lactate threshold and distance running performance in young and old endurance athletes. J Appl Physiol 58:1281–1284

Bar-Or O (1987) The Wingate anaerobic test. An update on methodology, reliability and validity. Sports Med 4:381–394

Beaver WL, Wasserman K, Whipp BJ (1986) Improved detection of the lactate threshold during exercise using a log-log transformation. J Appl Physiol 59:1936–1940

Bulbulian R, Wilcox AR, Darabos BL (1986) Anaerobic contribution to distance running performance of trained cross-country athletes. Med Sci Sports Exerc 18:107–113

Conley DL, Krahenbuhl GS, Burkett LM, Miller AL (1981) Physiological correlates of female road racing performance. Res Q Exerc Sport 52:441–448

Costill DL, Daniels J, Evans W, Fink WJ, Krahenbuhl G, Saltin B (1976a) Skeletal muscle enzymes and fiber composition in male and female track athletes. J Appl Physiol 40:149–154

Costill DL, Fink WJ, Pollock ML (1976b) Muscle fiber composition and enzyme activities of elite distance runners. Med Sci Sports 8:96–100

Costill DL, Fink WJ, Flynn M, Kirwan J (1987) Muscle fiber composition and enzyme activities in elite female distance runners. Int J Sports Med [Suppl] 8:103–106

Daniels J, Krahenbuhl G, Foster C, Gilbert J, Daniels S (1977) Aerobic responses of female distance runners to submaximal and maximal exercise. Ann NY Acad Sci 301:726–733

Daniels J, Scardina N, Hayes J, Foley P (1986) Elite and subelite female middle- and long-distance runners. In: Landers DM (ed) Sport and elite performers. Human Kinetics, Illinois, pp 57–72

Farrell PA, Wilmore JH, Coyle EF, Billing JE, Costill DL (1979) Plasma lactate accumulation and distance running. Med Sci Sports Exerc 11:338–344

Favier R, Constable SH, Chen M, Holloszy JO (1986) Endurance training reduces lactate production. J Appl Physiol 61:885–889

Graves JE, Pollock ML, Sparling PB (1987) Body composition of elite female distance runners. Int J Sports Med [Suppl] 8:96–102

Holloszy JO, Rennie MJ, Hickson RC, Conlee RK, Hagberg JM (1977) Physiological consequences of the biochemical adaptations to endurance exercise. Ann NY Acad Sci 301:440–450

Hurley BF, Hagberg JM, Allen WK, Seals DR, Young JC, Cuddihee RW, Holloszy JO (1984) Effect of training on blood lactate levels during submaximal exercise. J Appl Physiol Respir Environ Exerc Physiol 56:1260–1264

Jacobs I (1986) Blood lactate: implications for training and sports performance. Sports Med 3:10–25

Karlsson J, Holmgren A, Linnarson D, Astrom H (1984) OBLA exercise stress testing in health and disease. In: Lollgan L, Mellerowicz H (eds) Progress in ergometry: quality control and test criteria. Springer, Berlin Heidelberg New York Tokyo, pp 67–91

Kumagai S, Tanaka K, Matsuura Y, Matsuzaka A, Hirakoba K, Asano K (1983) Relationships of anaerobic threshold and the onset of blood lactate accumulation with endurance performance. Eur J Appl Physiol 52:51–56

Pate RR, Sparling PB, Wilson GE, Cureton KJ, Miller BJ (1987) Cardiorespiratory and metabolic responses to submaximal and maximal exercise in elite women distance runners. Int J Sports Med [Suppl] 8:91–95

Powers SK, Dodd S, Deason R, Byrd R, McKnight T (1983) Ventilatory threshold, running economy and distance running performance of trained athletes. Res Q Exerc Sport 54:179–182

Stanley LJ, Brubaker CE (1973) Biomechanical and neuromuscular aspects of running. In: Wilmore JH (ed) Exercise and sports science reviews, vol 1. Academic Press, New York, pp 189–216

Tanaka K, Matsuura Y (1984) Marathon performance, anaerobic threshold, and onset of blood lactate accumulation. J Appl Physiol Respir Environ Exerc Physiol 57:640–643

Tanaka K, Matsuura Y, Matsuzaka A, Hirakoba K, Kumagai S, Sun-O S, Asano K (1984) A longitudinal assessment of anaerobic threshold and distance running performance. Med Sci Sports Exerc 16:278–282

Tanaka K, Nakazawa T, Hazama T, Matsuura Y, Asano K (1985) A prediction equation for indirect assessment of anaerobic threshold in male distance runners. Eur J Appl Physiol 54:386–390

Williams C, Nute ML (1983) Some physiological demands of a half-marathon race on recreational runners. Br J Sports Med 17:152–161

Yoshida T (1986) Relationship of lactate threshold and onset of blood lactate accumulation as determinants of endurance ability in untrained females. Ann Physiol Anthropol 5:205–209

Yoshida T, Chida M, Ichioka M, Suda Y (1987) Blood lactate parameters related to aerobic capacity and endurance performance. Eur J Appl Physiol 56:7–11

Yoshida T, Udo M, Iwai K, Muraoka I, Tamaki K, Yamaguchi T, Chida M (1989a) Physiological determinants of race walking performance on female race walkers. Br J Sports Med 23:250–254

Yoshida T, Udo M, Chida M, Ichioka M, Makiguchi M (1989b) Dietary iron supplement during severe physical training in competitive female distance runners. Sports Tr Med Rehabil 1:(in press)