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ORIGINAL ARTICLE

The relationship between vLTP and vVO_{2max} during an incremental test to exhaustion in professional endurance runners

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Abstract The minimal running velocity at which maximal oxygen uptake (VO_{2max}) is elicited during an incremental test to exhaustion has been used to prescribe training for competitive middle- and long-distance runners. The purpose of this study was to determine the relationship between velocity at lactate turnpoint (vLTP) and vVO_{2max} in long-distance runners. For this purpose 11 highly trained endurance runners were selected randomly from the national team. The average age, height and mass of the subjects were 24.36±1.1 years, 1.73±0.02 m and 63.25±21 kg respectively. The first test was used to determine vVO_{2max} and VO_{2max} (a continuous run to exhaustion with the start velocity at 10 km/h and the velocity increased 1 km/h per minute). The second test was used to determine vLTP (start velocity was 10 km/h and velocity increased 1 km/h for 4 min to reach lactate concentration over 5 mmol/l). The average VO_{2max} and vVO_{2max} of subjects were 58.54±2.8 ml/kg/min and 19±0.29 km/h respectively. Pearson's correlation coefficient and SPSS 12 software were used for analysing data. There was a positive moderate correlation between vLTP and vVO_{2max} (p=0.037, r=0.63). This study may indicate that, the more the athlete is capable of delaying the accumulation of his/her lactate, and the higher the velocity at which the accumulation takes place, the higher vVO_{2max} he/she can have. On the other hand, coaches can design training programmes at vVO_{2max} intensity to promote a higher vLTP.

Key words Maximal oxygen uptake · Running · Velocity at lactate turnpoint · Velocity at VO_{2max}

Introduction

Along with the new records achieved in the world and Olympic competitions, sports physiologists strive to determine the effective stimuli in athletes' performance development through different methods. Maximal oxygen uptake (VO_{2max}), running economy (RE), lactate threshold (LT), percentage of slow twitch muscles, and the effective method are the important factors in endurance performance [1, 2].

Different studies that have been carried out on this issue suggest that training in VO_{2max} intensity is the best way of increasing VO_{2max} in endurance athletes [3]. Since reaching and maintaining VO_{2max} is a predictive factor of endurance performance, one of the effective factors in this regard is training with velocity at VO_{2max} (vVO_{2max}) intensity. The minimal running velocity at which VO_{2max} is elicited in long–middle endurance running is called vVO_{2max} and it is a predictor of training intensity for endurance runners [4]. Recently there has been much focus on evaluation of training responses in the velocity related to the VO_{2max} [5]. In 1984, Billat and Koralsztein introduced the phrase "ve-

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locity at VO_{2max}" with its abbreviation vVO_{2max} [6]. It has been said that vVO_{2max} is a useful index which combines the VO_{2max} with movement economy and shows them as one factor. It also can describe the aerobic differences between different runners and categorise them. vVO_{2max}, unlike VO_{2max} and movement economy, describes the individual differences of runners during running [6].

Moreover, Pugh analysed the ways of determining the vVO_{2max} by two protocols [7]. Fifteen elite runners participated in their study. Subjects' vVO_{2max} were measured by an incremental treadmill test (the velocity which increased 1 km/h per 2 min) and running on a track. Comparing these two protocols showed that there is a significant difference between two ways of determining vVO_{2max}, but the difference is not too large (vVO_{2max}=21.1±0.7 km/h on a treadmill and vVO_{2max}=20.1±0.7 km/h on a running track).

Esfarjani studied the effect of interval training on aerobic capacity of lactate parameters and the duration of a 3000 m run of trained runners. Twenty 3000 m runners after 10 weeks of training of two sessions per week showed that taking advantage of vVO_{2max} intensive training can improve the performance of 3000 m runners [8]. However, the minimal running velocity at which VO_{2max} is elicited is important for performance time in 1500 m to marathon runners [5]. Findings also indicate a significant relationship between performance time of 3000 m, 5000 m, 10,000 m and vVO_{2max} in trained runners [9].

Another factor that affects the performance of endurance runners is lactate accumulation and increase of H+ in active skeletal muscle [10]. The complicated procedure of lactate concentration is the reason for fatigue during intensive training [3]. The velocity at lactate turnpoint (vLTP) is the point in the blood lactate velocity curve associated with a second sudden and sustained increase in blood lactate concentration over 5 mmol [3, 11, 12]. vLTP plays a significant role in training intensity at lactate accumulation in direct or indirect manner. It also explains the positive training intensity. vLTP is the good significant for training intensity at lactate accumulation whether directly or in directly, and explains the positive training intensity. Despite the significant relationship between vVO_{2max} of runners and exhaustion and also performance times of different runs, delay in lactate accumulation and velocity at which lactate accumulates have a high correlation with endurance performance [9, 13].

Regarding the vast range of variables in planning training sessions and considering the different reports, the importance of each parameter to planning a suitable and effective programme is controversial. The vVO_{2max} is a suitable index to determine the training intensity and is capable of calculating the exhaustion time. The velocity at lactate concentration of 5 mmol is another index and attempts have been made to measure the relationship between these two indexes to find out whether they can be used in planning training sessions to take advantage of an individual's vLTP, which affects their vVO_{2max}. Therefore, the purpose of the present study was to study the relationship between vLTP and VO_{2max} of professional endurance runners during an incremental test.

Materials and methods

Subjects

After necessary coordination with the Track and Field Federation and describing the purpose and the method of research, the top 1500 m, 3000 m, 5000 m and 10,000 m runners were introduced by the federation. At the beginning the number of subjects was 20, but this was reduced to 11 when 9 of them withdrew their cooperation. Eleven elite endurance and half-endurance runners (9 men and 2 women) gave their written agreement to continue participating. They were accommodated in the Azadi Sport Complex to undergo the related tests. All subjects presented at the Physical Assessment Center of the National Olympic Academy. Three of them performed the sample tests before data collection. Before the test, information regarding subjects' height, mass, body fat percentage and body mass index (BMI) was collected by In body 3.0.

Protocols

Each subject performed two separate tests to exhaustion on the treadmill on two different days, with each test separated by a period of at least 48 h. Metabolic data and VO_{2max} and vVO_{2max} measurements were collected using an online gas analyser system ($K4b^2$ model, Italian Cosmed product) through the treadmill exercise test periods. Breath by breath data was retrograde stationary time averaged over 15 s for the first test. On each occasion, the test was preceded by a 5 min self-selected warm-up typically at a speed of 8 km/h. The time between completion of warm-up and the start of any test was approximately one minute inactive rest. Initial treadmill velocity was set at 10 km/h in each test (0° slope).

Determination of VO_{2max} and vVO_{2max}

Considering similar studies to measure VO_{2max} and vVO_{2max} in endurance runners, an incremental test on treadmill was performed to exhaustion. The velocity was increased by 1 km/h every minute thereafter until voluntary exhaustion. VO_{2max} determination criteria were:

– no increase in amount of oxygen or VO_{2max} despite the velocity increase;
– more than 50% increase in RE; and
– increase of heart rate more than 90% of determined maximal heart rate (age–220) [1].

Determination of vLTP

Few studies have been reported regarding vLTP measurement. In this study the method of Smith and Jones [12] and Midgley et al. [3] was used to measure vLTP. The level of blood lactate was measured by a lactometer (Scout FDA, Germany). It was measured twice before the warm-up and 10 min after the warm-up. The speed was increased by 1 km/h after each phase. Each phase consisted of 4 min activity followed by measuring the subjects' blood lactate by lactometer during one minute inactive rest standing next to the treadmill by taking a blood sample from finger tip. vLTP is the running velocity before observation of a second sudden and sustained increase in blood lactate concentration over 5 mmol.

Statistical analysis

Pearson's correlation statistical method was used to measure the relationship among variables. The relationship between data and the determination of the level of their significance ($p<0.5$) was measured using SPSS software.

Results

Subjects' characteristics are shown in Table 1. In Table 2 mean and standard deviation of variables during two protocols are illustrated (the first protocol: measurement of VO_{2max} and vVO_{2max}; the second protocol: measurement of vLTP). The results gained through analysing the data are expressed in Table 3.

Table 1 The distribution of indexes of descriptive statistics of endurance runners (n=11)

Variable	Mean	Standard deviation
Age (years)	24	3.67
Height (m)	1.73	0.02
Mass (kg)	63.25	7.27
Body fat (percent)	13.50	3.49
BMI (km/m^2 in men)	21.04	1.28
BMI (km/m^2 in women)	19.8	0.7

Table 2 The mean and standard deviation of VO_{2max}, vVO_{2max} and vLTP of endurance runners (n=11)

Variables	Mean	Standard deviation	Minimum	Maximum
VO_{2max} (m/kg/min)	58.18	8.028	48	67
vVO_{2max} (km/h)	18.55	1.29	16	20
vLTP (km/h)	16.36	1.57	14	19

Table 3 The relationship between VLTP and vVO_{2max} of endurance runners (n=11)

Variables	(r)	(v)	p-value
vLTP and vVO_{2max}	0.63	39	0.037

Discussion and conclusions

The purpose of this study was to determine the relationship between vLTP and vVO_{2max} in long-distance runners. A positive significant relationship between vLTP and vVO_{2max} of elite runners was observed (r=0.63, p=0.037). Coefficient of determination showed that (v=39) 39% of vLTP of endurance runners can be affected by vVO_{2max}.

It is expected that the blood lactate concentration increases by the increase in work intensity and the amount of VO_{2max}. The lactate removal also increases simultaneously. Increase in training intensity will cause an increase in fast twitch muscle involvement, glycolysis, plasma epinephrine and lactate production [14]. Hill and Lupton showed that oxygen uptake during training increases by the increase in speed and continues till the speed reaches 256 m/min [15]. At this special speed, there is no increase in oxygen uptake and as a result heart, lungs, blood circulation and oxygen system will not be able to distribute the oxygen to the muscles due to the oxygen deficit. At speeds higher than this special speed, the body needs more oxygen and since the body cannot provide the necessary oxygen, the oxygen deficit will increase [15]. Concerning this issue, there is a critical speed for everyone at which the VO_{2max} is not enough and will lead to lactate concentration and exhaustion afterwards [6]. Moritani and colleagues explained this speed as the critical speed or vVO_{2max} and believed that this speed is very close to velocity lactate threshold [16]. Volkov and colleagues indicated that this speed measures the maximal aerobic capacity [17].

vVO_{2max}, which is used for training and performance prediction of long–middle distance runners, has been studied several times since 1923. It has been revealed that it is a useful index to indicate the individual differences during training and competition and shows the aerobic differences between different runners [6].

Moreover, vLTP, the velocity of lactate accumulation, indicates the tolerance of a person toward lactate concentration and if they have a higher vLTP it means they have good tolerance [6]. Also, higher vLTP shows a delay in lactate accumulation [18]. According to this we can predict that the higher vLTP one has, the slower the velocity of lactate accumulation will be and VO_2 kinetics will be increased [3]. So regarding the slow speed of lactate accumulation, the athlete can receive his VO_{2max} at a faster velocity since the lactate accumulation will start at a higher speed. While a person reaches his VO_{2max} the lactate concentration in those whose vLTP and vVO_{2max} are very different will be faster and decrease time to exhaustion [3]. Therefore, concerning the positive relationship between vLTP and vVO_{2max}, coaches can measure these indexes to change the intensity of training and then by shortening the differences between vLTP and vVO_{2max} can delay their lactate accumulation phase. However, more studies in this regard are needed to prove this. We can measure the vLTP of runners in different running events, which may lead to a special vLTP for each event.

Conflict of interest statement The authors declare that they have no conflict of interest related to the publication of this article.

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