A 5 day hiit crash block with low time at high vo2 values may lead to rapid lactate threshold improvements in well-trained endurance runners. A case report

Supplementary materials: none
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ABSTRACT

Lactate threshold and the overall lactate profile (a curve trendline between lactate levels and velocity) are important biomarkers for endurance running performance. Lactate values at given running velocities are race time predictors in endurance events, and in case of predicting an unsatisfactory result in running competitions, urgent actions to improve endurance running performance are needed. HIIT crash blocks prior to race can be used as such option but existing experiments were performed on athletes in other than running sports. In this study we performed an experiment on an well-trained endurance runner, in this experiment a short time (5 days) high intensity interval training (HIIT) crash block leads to rapid improvements in his lactate profile. It's important to add that the time at high vo2 values during the HIIT session was very low but the lactate production was very high, which may suggests the discovery of a new mechanism for improving the lactate profile of an athlete.

INTRODUCTION

Competitive endurance running requires developed aerobic biomarkers in athletes. Vo2max, lactate threshold and running economy have been considered as one of the most important race predictors in endurance running events [1]. A high lactate value is an indicator of approaching fatigue and exhaustion and that this given exercise intensity is definitely high. A high lactate value is also associated with arterial and muscular hypoxia [2], acidosis (but not a cause of it) [3] and accelerated glycogen depletion rate as anaerobic glycolysis produce only 2 ATP molecules instead of 36 when oxygen is used. Lactate values at a given velocity may be used as race time predictors in endurance running events [4] and velocity at lactate threshold can be hold for approximately 25 minutes [5]. It is highly likely that if the athlete's lactate at a given velocity gets lower from training, or if the lactate threshold pace becomes higher, that this may lead to better endurance running performance. Additionally, lactate threshold may be associated with all cause mortality in patients, and belonging to the worst lactate threshold group is associated with the highest mortality rate [6].
So we can conclude that targeting the lactate curve is part of endurance and health engineering.

Athletes lactate profile is a complex phenomena. It is dependent on oxygen supply, which is a function of pulmonary function, cardiac output, hemoglobin mass , blood volume, muscle capillary-to-fiber ratio, muscle oxidative characteristics. Some of this variables can be rapidly changed, other needs more time for adaptation processes [7]. It is widely accepted by coaches that the so called threshold (or tempo) runs are the key workout for improving the lactate profile of an endurance runner, but this statement was refuted by science [8-11]. Instead, high intensity interval training [12], high volume low intensity training, resistance exercise and plyometrics has provided evidence of improved lactate profiles in athletes [13]. These training modalities are already used by well trained athletes and it’s harder to get improvements over time as the athlete progresses. Elite endurance athletes and exercise non-responders are the most difficult subjects which can get further improvements from training so different approaches are needed. Moreover, there are conditions where rapid lactate profile improvements are urgently needed, for example, in upcoming competitions where time for training is limited.
HIIT crash blocks has been used by exercise physiologists, endurance engineers and coaches as a desperate shock-microcycle in order to get rapid improvements prior to race events. This approach has been proved effective in elite cyclists [14] and alpine skiers [15]. As to our knowledge, hiit crash blocks had not yet been tested in endurance runners, that’s why we have decided to perform a hiit crash block on an already well trained endurance runner with a low-to-no exercise responsive phenotype and measure his lactate profile. In accordance to Midgley et.al [16] and Wenger and Bell [17] accumulated time at high vo2 values during a HIIT session is important vo2max improvement induction. Due to imperfect oxygen uptake kinetics the first time after initiating a HIIT bout, ATP is generated through anaerobic pathways where high amounts of lactate are been generated. We decided to perform a HIIT protocol where the time accumulated at high vo2 values is low, because we want to investigate a hypothesis that such protocols will lead to improvements in athletes lactate profile rather in vo2max.

CASE REPORT

Our subject is a 36 year old well trained endurance runner with a 6 year old experience and a vo2max of 60ml\kg\min. His 200m personal best is 29 seconds, 1k: 2:58,6, 5k: 19:20. And he asked us whether he can do a sub1:30 half marathon (which needs a sub 4:16 min\km pace). His vo2max value is in the range of a well trained athlete (60ml\kg\min) but more important, his initial lactate profile indicates that his target race pace is significant above his lactate threshold.

Training intervention

A graded treadmill based test was performed 1 week prior to this training intervention in order to find out the vo2max. The treadmill incline was set to a fixed 1% value and initially the speed was 7 km\h and increased every 1min until exhaustion. Oxygen consumption was measured by Vo2master (Canada) as a 20s moving average and was 60 ml\kg\min. The initial lactate profile test was performed on morning Wednesday, day 0. The next day 1h low intensity run (5:30 min\km) was performed.
On day 2-6 a 3*7*30"hard run\15"jog HIIT was performed, the rest between series was 3 min as in Ronnestad's work [18]. On day 2 the HIIT was performed with the Vo2master gas analyzer and lactate samples were collected. On day 7 a repeated lactate test was performed.

Lactate profiling and threshold determination.

Lactate was measured with a LactatePlus device (Nova Biomedical). The lactate profile test was performed 2,5h after a standardized meal (carbohydrates + coffee).
After initial 10 min warm-up (performed at a very low intensity (RPE 1\10, 7:00 min\km) our subject was paced by a sub-elite (vo2max 65) runner on a calibrated 400m running track (Luzhniki, north core, 1st lane, Moscow, Russia).
After 5-6 minutes running at constant pace (starting from 5:45 min\km) his ring finger tip was pierced by a 0,3mm lancet, the first blood drop was removed by an alcohol wipe, and then, after a second visually confirmed second blood drop was formed, it was collected by an experienced exercise physiologist. After the lactate value was obtained, a next running interval was performed (-30s per km pace), until lactate reached 4mmol\l.

The test was performed with the same shoes, designed for high intensity interval training (Nike Tempo Next) and under the same weather conditions. The athlete was asked to run behind the pacer to minimize wind influence. Heart rate data were collected via a chest strap (Polar H10). After lactate data was collected, a mathematical method was used to determine lactate threshold. A plot was formed from the lactate data, where x axis is speed, y axis is lactate (Excel, Microsoft). The lactate points were transformed into a third degree polynomial trendline ($Y=ax^3+bx^2+cx+d$), and the third degree equation was calculated by inserting 4 as the y value. The longest perpendicular was determined as an extreme point from the difference Y=Ypoly-Ylin, and the X value of the extreme point was set as the lactate threshold of our athlete

Results

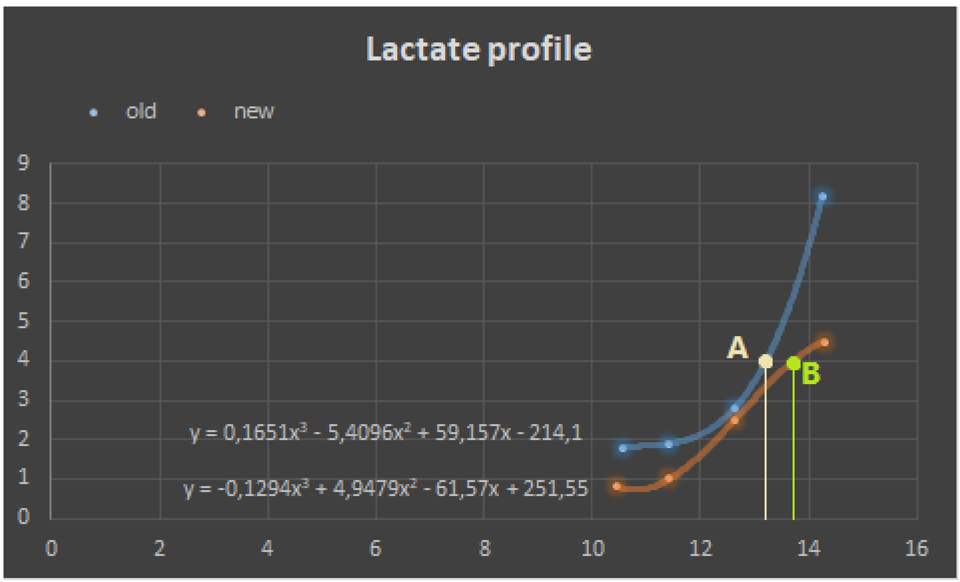
Vla4

To calculate the velocity at la=4, two third degree equations were formed form the lactate data from the old and the new (repeated) lactate test.

The first equation is y = 0,1651x3 - 5,4096x2 + 59,157x - 214,1. Bu inserting 4 as an Y value the x value corresponding for the vla4old speed is ~13,2 km\h (or 4:33 min\km pace).

The new equation from the repeated lactate test is y = -0,1294x3 + 4,9479x2 - 61,57x + 251,55 and the vla4new speed is ~13,7 km\h (or 4:23 min\km pace).

Vla4old and Vla4new velocities can be seen on the following plot as points A and B respectively.



Lactate at different velocity values

As shown in plot 2, lactate levels were definitely lower during all 4 measurements, where measurement 1, 2 and 4 (slightly faster his desired race pace) are lower more significant.

The speed value for point 1 is:

10,56 km/h (old test) and 10,46 km/h (new test)

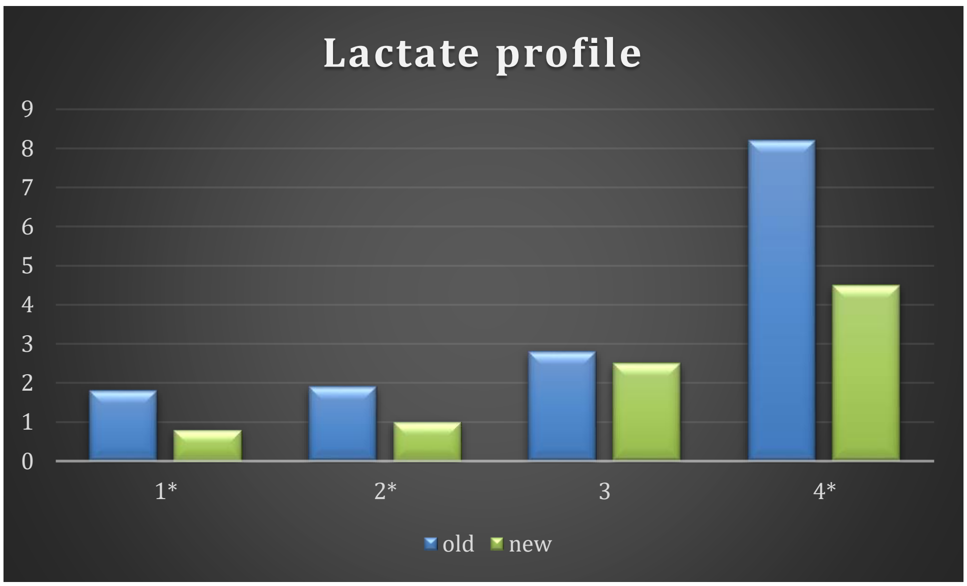
The speed value for point 2 is 11,43 km/h for both old and new tests.

The speed value for point 3 is 12,63 km/h for both.

And the speed value for point 4 is 14,25 km/h and 14,28 km/h for old and new test respectively. This little difference in speed is common during track and field tests and does not play a significant role.

We see a 1,8 fold lower lactate level at point 4 which indicates significant aerobic improvements and adaptations, and we are expecting a better time to exhaustion and exercise tolerance at similar paces.

Further improved tolerance in the short term can be achieved by using shoes with carbon planes and nitrate supplements (which may improve running economy) so a sub1.30 half marathon seems possible for our test subject under current aerobic fitness.



Oxygen consumption during HIIT

54, 57, and 60ml\kg\min were set as 90%, 95% and 100% of vo2max values. Time spent above this zones were calculated manually in Excel.

Lactate after immediately HIIT: 18,4 mmol/l

Rate of perceived exertion: 9,5/10

Discussion

In this study we have shown that a short 5 day HIIT crash block can lead to rapid improvements in lactate profiles of endurance runners. Short HIIT sessions may lead to activation of oxidative enzymes, which may be involved in lactate kinetics. In Skovgaard et.al publication, 6 30 sec all out sprint interval sessions followed by endurance exercise leads to upregulation of PGC1a which is a master regulator of mitochondrial biogenesis in skeletal muscles. PDK-4 and VEGF, which are also involved in lactate kinetics (by modulating lactate generation and capillary-dependent muscle oxygen supply) are also upregulated [19]. In our study the intensity was lower than all out, but definitely high (somewhere near vvo2max or even anaerobic speed reserve (ASR) range) and there is no evidence that a truly all out sprint will induce different adaptation mechanisms than a vvo2max\ASR HIIT. Sprint intervals (and maybe also short vvo2max\ASR HIIT) upregulates oxidative enzymes in high speed muscle fibers which will decrease vlamax, a biomarker for maximal lactate production rate [20]. Time at high vo2malues during HIIT are considered good for aerobic fitness developments and vo2max improvements [21, 22], but the low accumulated time at high oxygen consumption by our runner give us a clue that high time at high vo2 values may not be achievable with this time of HIIT, because in the jogging phase the oxygen consumption goes rapidly down and a value above 90%Vo2max is achieved only for seconds. This observation give us a hint that other then time at high vo2 values mechanisms are involved in lactate profile improvements, for example, lactate, generated from muscles can act as a signaling molecule. Lactate per se is not a cause of acidosis but more a molecule required for exercise induced adaptations [23]. We speculate that if our tested subject spend very low time at high vo2 values, his ATP was produced more from anaerobic glycolysis and so we may conclude that a huge amount of generated lactate during this crash hiit block may be responsible for the observed adaptations. We also belief that the statement that a high time at a high vo2 value is optimal for aerobic adaptation needs strong validation in large scale studies.

This study can provide exercise physiologists, athletes and coaches with useful hints how performance in events where lactate profile plays a huge role can be improved short term, this may be especially important as in elite performance sports as in health engineering. We make a cautious assumption that low time spend at high vo2max values may lead to a better lactate profile rather than vo2max improvements but further experiments are needed. Additionally, lactate acts as a microbiome modulator, by increasing the amount of Veillonella atypica in the gut. A high amount of Veillonella atypica was found in elite endurance athletes and it is possible that a high amount of generated lactate during this crash block may lead to improvements in lactate profiling [24]. in this study we did not perform a microbiome analysis, our assumption is made for future researchers. Hormetic response by reactive oxygen species (ROS) is one of the mechanisms of HIIT induced exercise adaptations and antioxidant supplements blunts exercise response. Upregulation of intracellular antioxidant defense systems happens in well trained athletes by HIIT [25] and a more strong antioxidant defense may be responsible for plateaus in aerobic fitness gains. A 5 HIIT crash block may lead to additional ROS production which may overcome this defenses and lead to further hormetic response.

Conclusion

Short term HIIT crash block may lead to rapid and significant improvements in lactate profiles in endurance runners which may translate to improved endurance running performance. This strategy can be used as an urgent treatment option by running coaches, exercise physiologists and performance engineers in case when the athletes lactate profile is unsatisfying prior to a running competition. Further larger scale experiments and mechanism-determining experiments are needed.

Contributions

Conception and design of the experiment: D. Varvanets

Preparation of the manuscript: D. Varvanets

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Data and Supplementary Material Accessibility

None

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