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THE EFFECT OF HIGH VS. LOW INTENSITY TRAINING ON AEROBIC CAPACITY IN  
WELL TRAINED MALE MIDDLE- DISTANCE RUNNERS

**Running head:** High Vs. Low Intensity Training

**Laboratory:** The Norwegian School of Sport Sciences

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## **ABSTRACT**

The purpose of this study was to examine the effect of two different intervention training regimes on VO<sub>2</sub>max, VO<sub>2</sub>max velocity (vVO<sub>2</sub>max), running economy (RE), lactic threshold velocity (vLT) and running performance on a group of well-trained male middle-distance runners in the pre-competition period. Twenty-six well-trained male middle-distance runners took part in the study. All participants were tested on VO<sub>2</sub>max, vVO<sub>2</sub>max, RE, lactate threshold (LT), vLT and a performance test. The participants were matched according to their pre-test results, then randomly assigned into one of two groups, a high volume (70 km) low intensity training group (HVLI-group); or a high-intensity low volume (50 km) training group (HILV-group). No significant differences were found between the two groups on all measures both before and after the intervention period. Furthermore, the HILV-group had a marked increase in vVO<sub>2</sub>max and vLT after the training period when compared to pre-test. Both groups had a marked improvement in RE. The performance test showed that the HILV-group made 456 m (1.38 min) and the HVLI-group 273 m (54 sec) in progress. The production of lactic acid was notably higher in the HILV-group (0.9 mmol) when compared to the pre-test. The findings show that male middle-distance runners tested in this study improved in vVO<sub>2</sub>max and vLT more when they train around LT than training with low intensity for a short period of 10 weeks.

## **KEYWORDS:**

Athletics; Endurance; Lactate anaerobic; VO<sub>2</sub> Max

## INTRODUCTION

Performance in middle- distance running in track and field is determined by aerobic and anaerobic capacity (17). The duration of the competitions in middle- and long- distance running points out the significance of aerobic capacity. In 800-m running, the athletes depend equally on both aerobic and anaerobic energy (30); where as 80 % of the energy needed in 1500-m running comes from the aerobic energy system (30). This underlines the strong relationship between aerobic capacity and performance in middle- distance running. The athlete's endurance capacity is determined by the level of maximal oxygen consumption ( $VO_{2max}$ ), fractional percentage of maximum oxygen consumption (%  $VO_{2max}$ ) and running economy (RE) (23, 25). Several studies (10, 11, 13, 15) indicate a strong relationship between those parameters and performance in endurance sport. Furthermore, research on middle- distance runners (8, 17, 20) shows a high correlation between  $VO_{2max}$  and running performance. However, other researchers (13, 22, 25, 36) have shown that there is a marked relationship between %  $VO_{2max}$ , RE and running performance. Foster & Lucia (2007) and Lucia et al. (2006) showed the significance of RE as the critical factor determining performance in middle- and long- distance running (13, 25). However, the study of Coyle (1995) showed that the velocity at lactate threshold ( $vLT$ ) has a higher correlation with running performance than  $VO_{2max}$ , %  $VO_{2max}$  and RE (9). This is probably due to the fact that  $vLT$  is determined by  $VO_{2max}$ , %  $VO_{2max}$  and RE (33). Recent research indicates however that velocity at maximal oxygen consumption ( $vVO_{2max}$ ) has a stronger relationship to running performance in middle- distance running (4, 17, 21, 33). The  $vVO_{2max}$  depends on an integrative contribution of aerobic and anaerobic energy abilities (8, 10, 21). Although several attempts have been made to construct a model of middle distance training (800-

m and 1500-m) a consensus of the optimal training volume and intensity distribution to maximize these adaptations remains elusive (2, 8). Research shows that the development of training methods have traditionally been based on short-term studies among untrained or moderately trained individuals coupled with anecdotal evidence from experienced coaches and successful athletes (35, 37). The physical adaptations that occur in untrained subjects remain unclear compared with highly trained subjects (24). Helgerud et al., 2007 indicate that in endurance training, the intensity provides the best training response for moderate and untrained athletes (15). Newer studies applied on well trained runners however, indicate a higher correlation between higher training volume on lower intensities and performance, than do training with higher intensities and performance (11, 12, 29). Furthermore, the reported studies indicate that training has to be performed with a relatively high volume on both high and low intensity to enhance performance in endurance athletes. No studies however have examined this relationship (combining training with low or high intensity) in a pre-competition period with well trained runners. Therefore, to enhance our knowledge of middle- and long- distance training, we need more specific information of how to periodize the distribution of the volume and the intensity in the daily training process in the different training periods (8, 28). Studies show that the most successful middle- distance runners perform a volume of 60-100 km per week in the different training periods (3, 12). The amount of training performed with high and low intensity to enhance performance in the pre-competition training however is openly discussed among coaches and researchers throughout the world. Presently there have been no well controlled studies to examine what is the most favorable model to enhance performance with well trained runners. Therefore, the purpose of the present study was to examine the effect of two different intervention training regimes (high intensity-low volume (82-92 % of VO<sub>2</sub>max);

and low intensity-high volume (65-82 % of VO<sub>2</sub>max)) on VO<sub>2</sub>max, % VO<sub>2</sub>max, vVO<sub>2</sub>max, RE, vLT and running performance on a group of well-trained male middle- distance runners in the pre-competition training period. This study brings forward supplementary information about the periodization of training volume and intensity in the pre-competition mesocycle (10 weeks) to reach the highest possible performance in a group of well-trained male middle- distance runners.

## **METHODS**

### **Experimental Approach to the Problem**

All the physical tests were performed on a treadmill (Woodway ELG 2, Weil am Rhein, Germany). The treadmill was calibrated for inclination and speed and had a gradient degree from 0 to +/- 30 % with a maximum speed of 30 km/h. An inclination of 1.7% was used for all physical capacity measurements to equalize the air resistance on the treadmill compared to running on the track. The inclination of 1.7% is a Norwegian standard for testing LT on the treadmill (7, 16). Lactate was analyzed by taking blood samples into a capillary tube and thereafter injecting them into a lactate analyzer having a mixing chamber (1500 Sport, YSI Inc., Yellow Springs Instr: Ohio, USA) with the help of a standard injector (20 µl Pipette). To monitor heart rate (HR) a pulse transmitter (Polar Sport Tester S610, Polar Electro OY, Kempele, Finland) was attached around the participant's chest. The pulse belt sent HR signals to a pulse watch (Polar accurex Plus, Polar Electro OY, Kempele, Finland). The VO<sub>2</sub> was measured through a two-ways mouth piece (Hans Rudolph Instr. USA) and a sling connected to O<sub>2</sub> and CO<sub>2</sub> analyzer (Oxygen Champion, Jaeger Instr; Hoechberg, Germany). The expired volume was measured with turbine (Triple V volume transducer, Germany).

The participants were matched according to their pre-test results in the performance test. Then they were randomly assigned into one of two groups, a high volume (70 km) low intensity (65-82 % of HR max) training group (HVLI-group); and a high-intensity (82-92 % of HR max) low volume (50 km) training group (HILV-group). The intensity zones used in this study were based on the elite endurance athletes' individual LT zone which is around 85-90 % of HR max (4).

Systematic testing of top-athletes in endurance events at the Norwegian Olympic training centre for the last 30 years show that the individual LT is about 87-88 % of HR max (37). Therefore, training in the intensity zone 65-82 % of HR max is recommended as a low intensity training regime, while training from 82-92 % is considered as a high intensity training regime around LT.

The study took part in the pre-competition phase of the training program for the participants. The length of the mesocycle was 10 weeks. The pre-tests and the post-tests were conducted on two separate days with two days rest in between. On test day one LT and VO<sub>2</sub>max were tested and the individual vVO<sub>2</sub>max, vLT and RE were calculated. On test day two a continuous performance time-trial test on the treadmill was conducted at the athletes' vVO<sub>2</sub>max.

## **Participants**

Twenty-six young well-trained males' middle- distance runners aged ( $\pm$  SD) ( $19.9 \pm 6.1$  years), body mass ( $69.8 \pm 5$  kg) and stature ( $179.4 \pm 5$  cm) volunteered to participate in the present study. The participants were all highly committed to training, running  $90 \pm 14$  km per week. The personal records for the participants in 800-m ( $\pm$  SD) was ( $2.03 \pm 0.04$  min), 1500-m ( $4.17 \pm 0.07$ ) and 3000-m ( $9.06 \pm 0.18$  min). The length of training for the participants was  $3.8 \pm 6.2$  years. All participants gave their written voluntary informed consent and the local ethics committee at the Norwegian School of Sport Sciences approved the study.

## Procedures

Test-retest performance reliability was conducted on all participants on 2 consecutive days (test day 1 and test day 2) one week before the actual testing took place. The test-retest was applied on those tests that we believe would have an influence on the results because of the learning effect ( $vVO_{2max}$ ,  $vLT$  and the performance test, respectively). Furthermore, to increase reliability and strengthen the validity of the testing procedures, the athletes were instructed to prepare mentally like they would do prior to important competitions and to keep up their normal routines for meals, sleep time and use of running equipment. The tests were performed under standard laboratory conditions. No actual training was performed on the day before the test day.

The exercise protocol on the first test day started with a 10 min warm up by running on a motorized treadmill at a speed of 9 km/h to establish a baseline value of  $VO_2$ , HR and blood lactate concentration ( $La$ ). Then a 6x5 min sub maximal incremental running test was performed at 10 km/h, 11.5 km/h, 13.0 km/h, 14.5 km/h, 16.0 km/h and 17.5 km/h., with 30s of rest between stages. HR and  $VO_2$  were measured during each running period. Blood samples from finger tips were taken 10s after finishing each of the 6 standardized running velocities. These values were used to calculate the LT and  $vLT$ . The LT was determined as the  $vLT$  that corresponded with 3-mmol lactate. A fixed value of 3-mmol lactate was shown to have the best correlation with direct LT measurement (7). The running economy (RE) was calculated by measuring the  $VO_2$  from 2 to 3.5 min during the lactate profile test. The mean  $VO_2$  presented in ml/kg/min was the measure of the RE for the athlete (16). The RE was determined by measuring  $VO_2$  during the final 1.5 min of all standardized intensities.

After a 15 min rest period, the VO<sub>2</sub>max was measured. The participants started to run at their vLT with a stepwise increase in velocity of 1 km/h per min until a plateau in their VO<sub>2</sub> was observed. If the participants could no longer continue and a plateau was not observed, the following criteria were set to accept the test result for further analyses: R value over 1.10, flattening of VO<sub>2</sub> for the last 30s of measuring, and HR closer to 5-8 beats below the athletes maximal HR (18). The duration of the test was 6 - 7 min.

On test day two, the participants warmed up on the treadmill for 15 min at 9km/h. Then the performance test was started after a 3 min rest. The test was performed by running at a speed corresponding to the athlete's individual vVO<sub>2</sub>max (10, 19). The duration of the test was between 5-6 min.

### **The training intervention**

The training volume and distribution of intensity in the intervention period (10 weeks) were thoroughly calculated and matched for total work and frequency. The difference in distribution of training intensity in the two intervention groups was compensated with the HVLI-group running some more km per week at a slower pace than the HILV-group did. The HILV- group ran a mean of 50 km per week and the HVLI- group ran a mean of 70 km per week. The participants in both groups were running 6 training sessions per week. The HILV-group performed 33 % of the total training volume at 82-92 % of HR max and 67 % was performed at 65-82 % of HR max. The HVLI-group performed 13 % of the total training volume at 82-92 % of HR max and 87 % was performed at 65-82 % of HR max. Furthermore, the HILV-group

performed 3 intensive workouts per week at 82-92 % of HR max and the HVLI-group performed one intensive workout per week. The Polar pulse watches were adjusted to beep if the intensity (HR) was more than  $\pm 5$  Beats per minute from the planned intensity target zone.

### **Statistical Analyses**

Raw data was transferred to SPSS 13.0 for Windows and Microsoft Excel for analysis. Intraclass correlation coefficient (ICC) was assessed on the data to examine reliability of performance. To detect differences in measures between pre and post test, paired t-test was performed to test for a difference in central location (mean) between the paired samples (within group). To test for a difference in central location (mean) between groups, the independent sample t- test was applied. Differences were considered significant at  $P \leq 0.05$ , and the results are expressed as means and standard deviation. The 95 % Confidence Interval (95% CI) was also calculated for all measures.

## RESULTS

\*\*\*\*\* Table 1 about here

Differences within groups and between groups of a variety of physiological measures are shown in Table 1. The results indicate that there were no differences within the HVLI-group from pre to post-test on all measured variables. Furthermore, the results indicate that there was a notable improvement within the HILV-group on velocity at VO<sub>2</sub>max and velocity at lactate threshold. A comparison between groups indicates that there were no notable differences between the two groups either at pre-test or post-test.

\*\*\*\*\*Table 2 about here

The HLVI-group had a notable decrease in VO<sub>2</sub> at running velocities of 10, 11.5, 13, 14.5, and 16 km/h (Table 2). This indicates a notable improvement in RE for the HVLI-group for those velocities. No change was observed at 9 km/h. Furthermore, the results show that the HILV-group also had a notable improvement in RE on all tested velocities except 11.5 km/h. When comparing the two groups, no marked differences were observed between them at pre-test or at post-test.

\*\*\*\*Table 3 about here

Within the HVLI-group no differences from pre to post-test were observed for the three performance test measure variables (Table 3). The HIVL-group had only a marked increase in the lactic acid concentration when compared to the pre-test for the same group. When comparing

between groups, there were no marked differences observed between groups at pre-test or at post test.

The day-to-day reliability of measurements gave an ICC of 0.88 for mean  $\dot{V}O_{2\max}$ , 0.92 for mean  $\dot{V}LT$ , and 0.91 for mean performance test.

## **DISCUSSION**

### **Lactate threshold velocity– vLT**

The results show that only the participants of the HILV-group markedly increased their vLT (Table 1). The vLT increased from 14.6 km/h in pre-test to 15.2 km/h in post-test. Due to the small intervention period in this study it can be said that the improvement in the HILV-group was large. Furthermore, research (23, 32) shows that improvements of the vLT are caused by development of the VO<sub>2</sub>max, %VO<sub>2</sub>max or RE. The improvement in vLT in this study could be explained by the improvement of RE and %VO<sub>2</sub>max. This indicates that specific training close to the LT will result in favorable improvements of the vLT. Similar results were found in the literature (5, 34). In this study, the improvement in vLT could not be caused by improvement in VO<sub>2</sub>max as there was no notable improvement in VO<sub>2</sub>max (Table 1).

### **VO<sub>2</sub>max**

Neither group improved their VO<sub>2</sub>max (Table 1). The reason could be due to the intensity of the training (6, 15, 35). The results indicate however, that this is not the probable explanation, since the training resulted in a marked improvement in anaerobic capacity. Another explanation could be that the period of intervention was too short for the participants to improve their VO<sub>2</sub>max. Furthermore, the participants in this study could have reached their VO<sub>2</sub>max potential after many year of extensive training. Longitudinal studies show that VO<sub>2</sub>max is developed fast and that elite athletes reach their highest values in their early twenties (19). Furthermore, progress made in the twenties is mainly caused by improved %VO<sub>2</sub>max, RE, and increased anaerobic capacity (19). Despite the fact that VO<sub>2</sub>max didn't increase; the HILV-group improved

markedly on  $vVO_2\max$  (Table 1). The  $vVO_2\max$  increased from 16.0 to 16.8 km/h. The improvement is probably explained by the marked progress the participants' made on RE and anaerobic capacity. This indicates that training around the LT is favorable for elite athletes in order to develop  $vVO_2\max$ . Since  $vVO_2\max$  is a parameter which correlates well with the ability to perform, training around the LT can be an effective intensity to develop performance in elite middle distance runners (4, 10).

### **% $VO_2\max$**

The results showed that neither group had any marked change in their % $VO_2\max$  at  $vLT$  (Table 1). The HILV-group decreased in their % $VO_2\max$  at  $vLT$ , this decrease could be caused by training sessions which were too short. Results from various studies indicate that elite athletes, with long competition times, often train more hours and have a higher % $VO_2\max$  than athletes whose competition times are shorter (1). The  $vLT$  of elite marathon athletes has been reported to be approximately 90%  $VO_2\max$ . Another explanation can be that the marathon athletes train more and have longer workouts around the LT than athletes whose competition time is under five minutes. In future studies of elite middle-distance athletes, one should study what effect the length of the training sessions and the intensity of training have on % $VO_2\max$ .

## **Running economy (RE) at five different speeds**

Both the HILV-group and the LIHV-group markedly improved their RE at most of the speeds during the LT test (Table 2). The progress was unexpected, since studies of elite athletes show that it takes months and years to develop high RE (19). It is important to improve the RE in order to develop the ability to make progress over years, and often that is the specific factor which can explain the differences in performance between successful endurance athletes on an elite level (13, 19, 27). Research indicates that to a large degree, the total length of workout can explain progress made in RE. This training can lead to transforming Type II fibers to Type I fibers and thus better the RE (2). Another conceivable effect is that many hours spent doing one specific form of activity can be necessary to develop running technique and with that RE. However, the results from this study do not indicate that there is such a connection. That could be a result of the intervention period being too short, and that the differences in intensity and training time between the groups too small. Other researchers have found that performing strength, plyometrics and speed training helps improve the RE in typical endurance sports (26, 31). In the future, one should carry out longitudinal studies where one studies the long term effect of endurance training with high and low intensity and compares those results to that with strength, plyometric and speed training.

## **Performance testing**

The results show no notable progress in the performance test (Table 3). This was surprising, since there is a good connection between vLT and the ability to perform in running (14). Furthermore, the results show that both groups on average run between 54-98 seconds longer at

the post-test (Table 3). Possibly a greater number of participants would result in performance test differences. In future surveys one could work hard to complete similar training studies with more participants.

## **PRACTICAL APPLICATIONS**

The main findings in this study, was that training close to the LT (HILV-group) resulted in better training effect among male middle-distance runners than training with low intensity (LIHV-group). The HILV-group had markedly improved in  $v\text{VO}_2\text{max}$  and  $v\text{LT}$ , anaerobic capacity and RE. The LIHV-group had only a notable improvement in their RE. As for all measured parameters in this study, there were no marked differences between the two groups before and after the intervention period. Future research should focus on the effect of endurance training with high and low intensity on a longer period. This could increase the understanding of the significance of intensity in order to develop aerobic and anaerobic capacity, and whether endurance training is more effective than strength, plyometrics and speed in order to improve the performance of middle-distance runners.

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<b>Table 1: Mean Results of VO<sub>2</sub>max, vVO<sub>2</sub>max, vLT and %VO<sub>2</sub>max at vLT between and within groups from pre to post-test.</b>												
<b>Variable</b>	<b>HVLI-Group (n=10)</b>				<b>HILV-Group (n=9)</b>				<b>Between Groups Difference</b>			
	<b>Pre-test</b>	<b>Post-test</b>	<b>Change</b>	<b>95% CI</b>	<b>Pre-test</b>	<b>Post-test</b>	<b>Change</b>	<b>95% CI</b>	<b>Pre-test</b>	<b>95% CI</b>	<b>Post-test</b>	<b>95% CI</b>
VO <sub>2</sub> max (ml·kg <sup>-1</sup> ·min <sup>-1</sup> )	70.4 ± 3.8	69.2 ± 3.6	-1.2 ± 2.8	-3.2 to 0.8	70.2 ± 2.7	71.4 ± 2.4	1.2 ± 2.4	-0.7 to 3.1	0.2 ± 1.5	-3.4 to 3.1	2.3 ± 1.4	-0.8 to 5.3
vVO <sub>2</sub> max (km/h)	16.6 ± 0.8	17.1 ± 0.7	0.5 ± 0.7	-0.1 to 1.0	16.0 ± 1.1	16.8 ± 0.8	0.8 ± 0.8*	0.2 to 1.4	0.6 ± 0.4	-1.5 to 0.3	0.2 ± 0.3	-1.0 to 0.5
vLT (km/h)	15.3 ± 0.8	15.7 ± 0.7	0.4 ± 0.7	-0.1 to 0.9	14.6 ± 1.0	15.2 ± 0.8	0.7 ± 0.7*	0.1 to 1.2	0.7 ± 0.4	-1.6 to 0.1	0.5 ± 0.4	-1.2 to 0.3
%Vo <sub>2</sub> max at vLT	84.0 ± 3.7	81.8 ± 3.0	-2.2 ± 3.9	-5.0 to 0.6	82.0 ± 3.2	80.0 ± 2.2	-2.0 ± 2.4	-3.8 to -0.2	2.0 ± 1.6	-5.4 to 1.4	1.8 ± 1.2	-4.4 to 0.8
* = Significant at p ≤ 0.05												
CI = confidence interval												

**Table 2: Mean results of V02 (Running economy) on five different running velocities (9km/h - 16.0 km/h) between and within groups from pre to post test.**

Velocity	HVLI-Group				HILV-Group				Between Groups Difference			
	Pre-test	Post-test	Change	95% CI	Pre-test	Post-test	Change	95% CI	Pre-test	95% CI	Post-test	95% CI
9 km/h	34.6 ± 2.9	34.1 ± 2.4	-0.4 ± 2.7	-2.4 to 1.5	36.1 ± 4.2	34.3 ± 3.6	-1.7 ± 2.1*	-3.3 to -0.1	1.5 ± 1.6	-1.9 to 5.0	0.2 ± 1.4	-2.7 to 3.1
10 km/h	39.1 ± 2.5	37.2 ± 2.3	-1.8 ± 1.7*	-3.0 to -0.6	39.1 ± 4.2	37.3 ± 3.8	-1.8 ± 1.8*	-3.2 to -0.4	0.1 ± 1.6	-3.2 to 3.3	0.1 ± 1.4	-2.9 to 3.1
11.5 km/h	44.1 ± 2.4	42.2 ± 1.8	-1.9 ± 1.5*	-2.9 to -0.8	44.7 ± 4.5	43.1 ± 3.6	-1.6 ± 2.6	-3.6 to 0.4	0.6 ± 1.6	-2.8 to 4.1	0.9 ± 1.3	-1.9 to 3.6
13 km/h	49.6 ± 2.3	47.5 ± 1.7	-2.1 ± 1.3*	-3.0 to -1.1	51.1 ± 3.8	48.7 ± 3.0	-2.4 ± 1.6*	-3.7 to -1.2	1.5 ± 1.4	-1.5 to 4.4	1.1 ± 1.1	-1.2 to 3.4
14.5 km/h	55.3 ± 2.7	52.8 ± 2.7	-2.5 ± 3.0*	-4.7 to -0.4	56.9 ± 3.3	55.1 ± 3.2	-1.8 ± 2.1*	-3.4 to -0.2	1.6 ± 1.4	-1.3 to 4.5	2.3 ± 1.4	-0.5 to 5.2
16 km/h	61.4 ± 2.2	59.0 ± 2.6	-2.5 ± 2.2*	-4.1 to -0.9	62.0 ± 3.0	60.4 ± 2.5	-1.6 ± 1.9*	-3.0 to -0.1	0.6 ± 1.2	-1.9 to 3.1	1.5 ± 1.2	-1.0 to 3.9

Variable	HVLV-Group				HILV-Group				Between Groups Difference			
	Pre-test	Post-test	Change	95% CI	Pre-test	Post-test	Change	95% CI	Pre-test	95% CI	Post-test	95% CI
<b>Running distance m.</b>	2559 ± 598	2778 ± 803	218 ± 546	-172 to 609	2546 ± 623	2848 ± 1144	301 ± 886	-341 to 944	13 ± 280	-604 to 578	69 ± 449	-879 to 1018
<b>Time in minutes</b>	8.2 ± 2.1	9.1 ± 2.9	0.9 ± 1.8	-0.5 to 2.2	8.4 ± 2.2	9.4 ± 3.9	1.0 ± 2.8	-1.1 to 3.2	0.1 ± 1.0	-1.9 to 2.2	0.3 ± 1.6	-3.0 to 3.6
<b>La</b>	8.1 ± 1.7	8.5 ± 0.9	0.4 ± 1.4	-0.6 to 1.4	7.2 ± 1.7	8.1 ± 0.8	0.9 ± 1.1*	0.1 to 1.7	0.9 ± 0.8	-2.5 to 0.8	0.4 ± 0.4	-1.2 to 0.5