

## Effect of Six Months Resistance Training on Lactate Threshold in Distance Runners

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### ABSTRACT

**Background:** The lactate threshold (LT) is the highest level of effort an athlete can keep up for a long time without causing a noticeable increase in blood lactate levels. Running long distances causes muscles to use more lactate, which forces the body to take lactate out of the bloodstream.

**Objectives:** This study aimed to investigate the effect of six months of resistance training based on lactate threshold in distance runners.

**Materials and Methods:** This study involved 100 subjects, randomized into experimental (age 24.72±3.26) and control group (age 24.56±3.07). Pre and post data collected at 0 and at the end of 6 months with warm up and cool down for 10 mins each.

**Results:** Statistically significant differences were seen in experimental group compared with control group in outcomes such as LT stage (3.82 vs 3.18), mean HR (160.02 vs 157.02), time taken to complete 5000m (18:13.8 vs 19:00.1) and running pace (4.5 vs 4.3) (P<0.005).

**Conclusion:** Our result suggests that the six months of resistance training on lactate threshold improve the distance running performance.

**Keywords:** Lactate Threshold, LT, Resistance training, Distance runners

### 1. INTRODUCTION

Track and field events originated in the late 19th century, typically involving athletes representing rival educational institutions and sports clubs. Competitive sports and athletics at national and international levels sparked significant interest in exercise physiology<sup>[1]</sup>. Numerous efforts have been made over the past century to understand human physiology by studying champion athletes and record-breaking performances<sup>[2]</sup>. Competitive distance running is a multifaceted discipline that includes endurance, mental resilience, and strategic execution, making it a rich area for research and exploration. Distance running ranges from 5000m to full marathon (42.19km/26.21miles). Resistance training is an exercise aimed at strengthening muscles in the body to achieve increased muscular strength, endurance, and power through resistance from external forces or weights. It may be a resistance band, free weights like dumbbells and barbells, weight machines, or other forms of loads through which body weight could serve as a form of resistance.

Although long-distance running is primarily an endurance-based activity, integrating resistance training into a runner's program leads to physiological and biomechanical improvements that translate to better performance by improved running economy, increased muscular strength, enhanced endurance performance, injury prevention, improved power, stride length and increased fatigue resistance<sup>[3]</sup>.

Anaerobic metabolism arises in the body when glucose breaks into the energy compound without enough oxygen, resulting in lactate synthesis. Lactate is initiated to serve both as a source of energy and a functional indicator of metabolic stress during prolonged high-intensity efforts, such as long-distance running<sup>[4]</sup>. Once exercise intensity is great, the lactate production rate will exceed the lactate clearance rate signifying a shift from largely aerobic metabolism towards greater reliance on anaerobic mechanisms. The most common cause of lowered muscle pH (metabolic acidosis) is the increase in hydrogen ion

concentration that is associated with accumulation of excess lactate. This given acidotic environment switches off muscle contraction, for instance by blocking the activity of energy-producing systems and reducing muscles' capacity to produce force<sup>[5]</sup>. In exhaustive all-out exercise, it is the lactate concentration which exceeds the rate at which effective clearance and elimination occur from the blood, the so-called lactate threshold (LT)<sup>[6]</sup>. This is shown by a pH dip from 7.4 to 6.8, which is believed to impair performance and induce weariness. In essence, lactate threshold training (LT) makes the body's physiology more robust in terms of lactate generation and lactic acid clearance<sup>[7]</sup>. It serves as a reliable gauge of how well the body converts chemical energy into mechanical energy. Blood lactate concentration measurements have been used widely for training control and performance detection. The metabolic processes of LT, VO2 max, and running economy are essential for endurance exercise and performance.

The lactate threshold is regarded by many researchers as the main predictor of endurance performance<sup>[8]</sup>. Furthermore, the LT seems to be the physiological measure that responds to endurance training the best, when compared to VO2 max and economy<sup>[9]</sup>. Lactate is a continuously produced and utilized essential fuel and potential signaling molecule, even under fully aerobic conditions, rather than being a waste product of anaerobic metabolism<sup>[10]</sup>. Reduced lactate clearance, increased activation of fast-twitch motor units, and an imbalance between mitochondrial respiration, glycolysis, and ischemia (low blood flow) or hypoxia (low blood oxygen concentration) are important causes of poor performance<sup>[11]</sup>.

## 2. MATERIALS AND METHODS

100 participants volunteered for the study, and they were randomized into Experimental (n=50) and control group (n=50). Subject's physiological data such as age, height (cms), weight (kgs), Body Mass Index (BMI), Resting respiratory rate and practice hours (Table 1) have been collected. Figure 1 illustrates the mean average of Male and Female. Participants suffered any recent trauma, neurological conditions, pregnancy, comorbidity such as hypertension, diabetes mellitus, cardiac issues and use of any ergogenic aids were excluded. Data collected in and around the sports complex of Navi Mumbai with prior filled consent form.

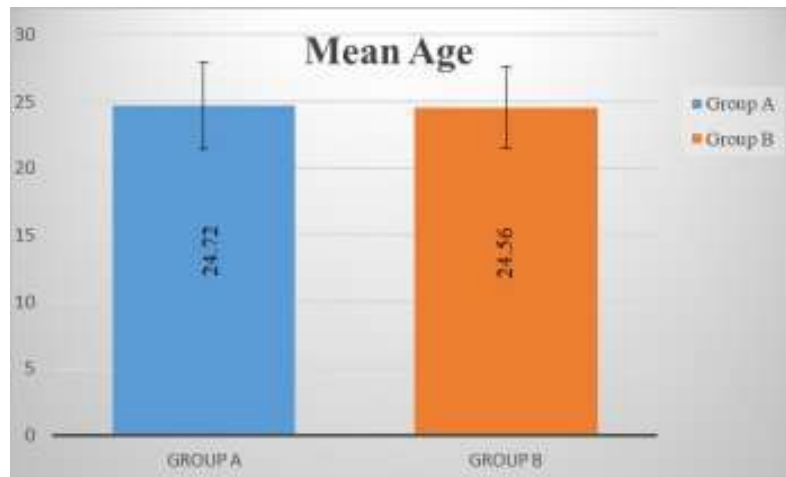
**Table 1: Demographic and Physiological characteristics of subjects at baseline**

|                | Group        | n  | Mean   | S.D.  | t     | P value |
|----------------|--------------|----|--------|-------|-------|---------|
| Age            | Experimental | 48 | 24.72  | 3.264 | 0.252 | .801#   |
|                | Control      | 47 | 24.56  | 3.072 |       |         |
| Height (cms)   | Experimental | 48 | 172.98 | 3.335 | 0.232 | .817#   |
|                | Control      | 47 | 172.78 | 5.108 |       |         |
| Weight (kgs)   | Experimental | 48 | 68.56  | 3.759 | 1.596 | .114#   |
|                | Control      | 47 | 67.28  | 4.248 |       |         |
| BMI            | Experimental | 48 | 22.90  | 1.127 | 1.501 | .136#   |
|                | Control      | 47 | 22.54  | 1.261 |       |         |
| Resting RR     | Experimental | 48 | 15.24  | 2.153 | 0.502 | .617#   |
|                | Control      | 47 | 15.02  | 2.227 |       |         |
| Practice Hours | Experimental | 48 | 2.28   | 0.497 | 2.237 | .028*   |
|                | Control      | 47 | 2.56   | 0.733 |       |         |

#p > 0.05 (non-significant)

\*p < 0.05 (Significant)

\*\*p < 0.01 (Highly Significant)



**Figure 1: Mean age Comparison between groups**

Randomizer software is used to allot the subjects by 1:1 with SNOSE technique, single blinded. Subjects Lactate Threshold (LT) were measured by making them run on the computerized treadmill (AFTON) based on Bruce Protocol and the blood sample drawn at the end of each stage. Blood lactate (BL) threshold is considered when the subject BL level shows 4 mmol/L. StatStrip Xpress 2 handheld lactate analyzer (NOVA Biomedical, USA) used to read the blood lactate level with the help of Lancet at fingertip. The heart rate was recorded by Polar H9 to record the mean heart rate. Dietary chart has been maintained as per guidelines by dietician [12,13,14].

Once the Lactate threshold level been estimated through Bruce Protocol (Table 2) [15,16,17], the experimental group received the training protocol (Table No. 3), where they made to run at their mean HR of LT  $\pm$  5 bpm for 3 months, and their intensity increased by 5% of mean HR of LT  $\pm$  5 till six months. The routine training sessions were conducted on the control group, and the data was collected at the end of six months and compared for the significance of the study. Five subjects lost the follow-up in the study due to personal reasons (Figure 2).

**Table 2: Estimation of Lactate Threshold (Bruce Protocol)** [15,16,17]

| Stage | Speed (mph/kmph) | Grade (Inclination) | Duration | Interpretation                                                                                                                                      |
|-------|------------------|---------------------|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| 1     | 1.7/2.7          | 10 %                | 3 min    | -60 sec recovery b/w each stage to collect blood sample and to record mean HR<br>-LT stage is where the lactate level is $\geq$ 72 mg/dl (4 mmol/L) |
| 2     | 2.5/4.0          | 12 %                | 3 min    |                                                                                                                                                     |
| 3     | 3.4/5.5          | 14 %                | 3 min    |                                                                                                                                                     |
| 4     | 4.2/6.8          | 16 %                | 3 min    |                                                                                                                                                     |
| 5     | 5.0/8.0          | 18 %                | 3 min    |                                                                                                                                                     |
| 6     | 5.5/8.9          | 20 %                | 3 min    |                                                                                                                                                     |
| 7     | 6.0/9.7          | 22 %                | 3 min    |                                                                                                                                                     |

**Table 3: Lactate Threshold Training Protocol** [15,16]

| Month                                                                      | Training Intensity                      | Frequency      |
|----------------------------------------------------------------------------|-----------------------------------------|----------------|
| 0-3                                                                        | Mean HR of LT ( $\pm$ 5)                | 1 session/week |
| 4-6                                                                        | Increase in 5% Mean HR of LT ( $\pm$ 5) | 1 session/week |
| * Warm up and cool down included for 10 min each in every Exercise session |                                         |                |

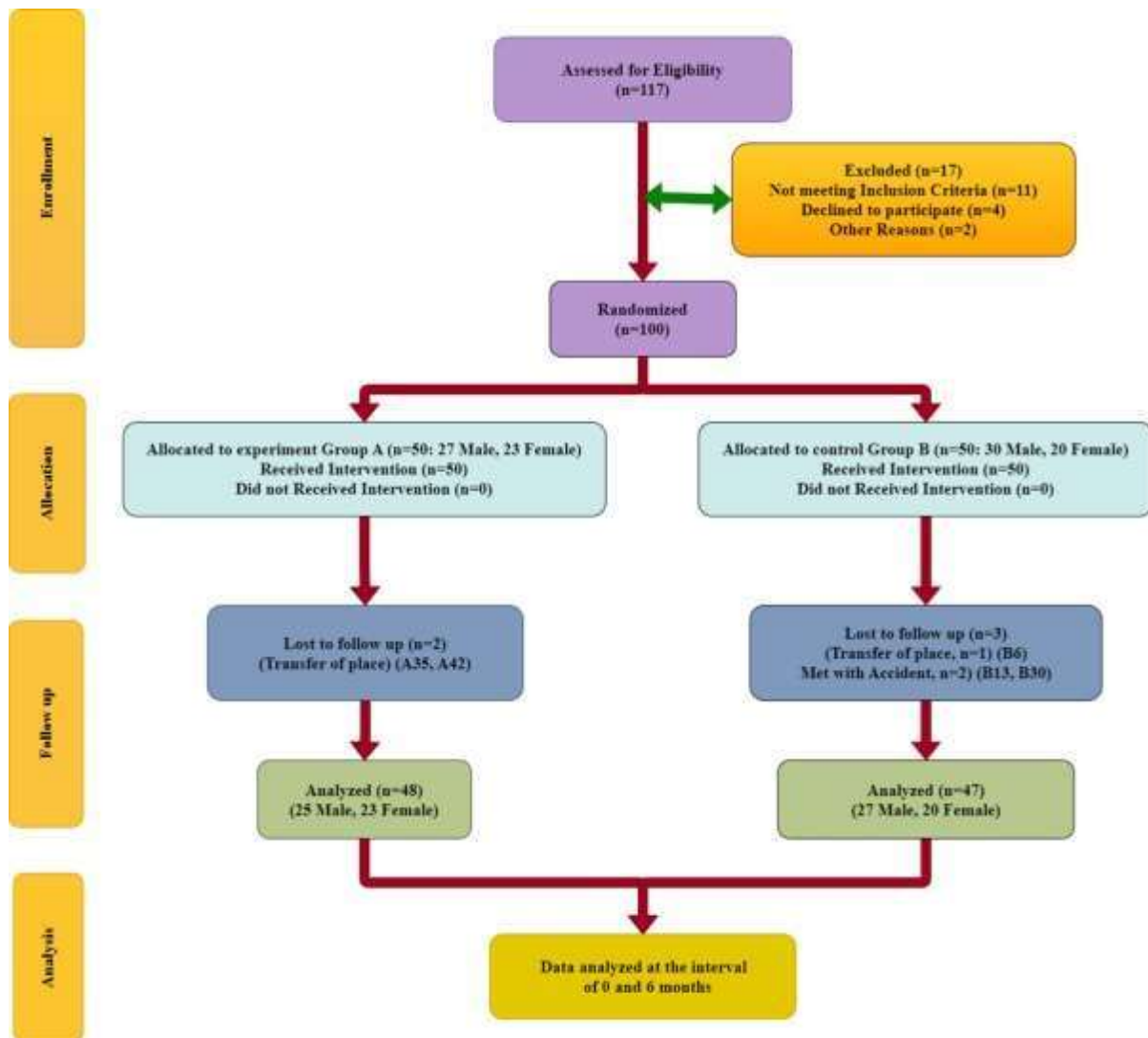


Figure 2: CONSORT Flow Chart

### Statistical Analysis

The SPSS (Version 26) software tool was used for statistical analysis. Means and standard deviations are used to represent the data. To compare groups, the unpaired t test is employed.

### 3. RESULTS AND ANALYSIS

There were no discernible differences between the groups at the start of the trial, except for practice hours where the control group practiced (2.56 h/day) more than the experimental group (2.28 h/day). End of six months training session the experimental group seen with significant differences in all outcomes such as LT stage, mean HR, time taken to complete 5000m and pace. The experimental group could reach the given target of 5000m by 124.39% more reduction in time (1 min 32 secs) than the control group, which improved by only 41 secs (t value 10.79,  $p < 0.05$ ). Their running pace

also increased by 7.14%, from 4.2 to 4.5 m/s, with a significant 29.49% increase in lactate stage from 2.95 to 3.82 (Table 4 and Table 5).

Table 4: The comparison of parameters at Baseline (0 months)

| Outcome                           | Group        | N  | Mean | S. D. | t    | P value |
|-----------------------------------|--------------|----|------|-------|------|---------|
| LT Stage/Level<br>(1/2/3/4/5/6/7) | Experimental | 48 | 2.95 | 0.41  | 0.47 | 0.562#  |
|                                   | Control      | 47 | 2.91 | 0.37  |      |         |

|                                     |              |    |         |         |      |        |
|-------------------------------------|--------------|----|---------|---------|------|--------|
| Mean HR                             | Experimental | 48 | 154.27  | 3.45    | 0.92 | 0.356# |
|                                     | Control      | 47 | 154.63  | 2.51    |      |        |
| Time Taken to 5000m(in secs)        | Experimental | 48 | 1185.67 | 73.03   | 0.81 | 0.412# |
|                                     | Control      | 47 | 1181.91 | 66.65   |      |        |
| Time Taken to 5000 m (hh:mm:ss.000) | Experimental | 48 | 19:45.6 | 00:41.2 | 0.71 | 0.212# |
|                                     | Control      | 47 | 19:41.9 | 00:39.6 |      |        |
| Pace (m/s)                          | Experimental | 48 | 4.2     | 0.25    | 0.41 | 0.314# |
|                                     | Control      | 47 | 4.2     | 0.23    |      |        |

Table 5: Comparison of Parameters at 6 months

| Outcome                             | Group        | N  | Mean    | S. D.   | t      | P value |
|-------------------------------------|--------------|----|---------|---------|--------|---------|
| LT Stage/Level (1/2/3/4/5/6/7)      | Experimental | 48 | 3.82    | 0.388   | 10.79  | 0.000** |
|                                     | Control      | 47 | 3.18    | 0.388   |        |         |
| Mean HR                             | Experimental | 48 | 160.02  | 2.412   | 10.065 | 0.000** |
|                                     | Control      | 47 | 157.02  | 3.292   |        |         |
| Time Taken to 5000m(in secs)        | Experimental | 48 | 1093.68 | 47.654  | 6.831  | 0.000** |
|                                     | Control      | 47 | 1140.04 | 30.724  |        |         |
| Time Taken to 5000 m (hh:mm:ss.000) | Experimental | 48 | 18:13.8 | 00:47.6 | 6.822  | 0.000** |
|                                     | Control      | 47 | 19:00.1 | 00:30.7 |        |         |
| Pace (m/s)                          | Experimental | 48 | 4.578   | 0.2063  | 6.714  | 0.000** |
|                                     | Control      | 47 | 4.382   | 0.1304  |        |         |

#### 4. DISCUSSION

Significant role of Resistance training on Lactate Threshold (LT) in distance runners seen in the aspects of time taken, pace, mean heart rate and lactate tolerance. The running efficiency of experimental could be improved due to better lactate clearance, enhanced blood flow and mitochondrial density enable faster lactate removal and thus delaying its accumulation. LT training raises the intensity level at which lactate begins to accumulate, allowing runners to sustain higher speeds before fatigue sets in. Improved buffering capacity led to adaptations in the muscles ability to neutralize hydrogen ions, mitigating the effects of acidosis <sup>[18]</sup>.

Resistance training at LT exhibited a stronger correlation and the ability to sustain a high fractional utilization of VO<sub>2</sub> max for a longer length of time postpones the onset of metabolic acidosis. distance running performance is superior to maximum aerobic capacity (VO<sub>2</sub> max). Training at LT intensity increases both aerobic and anaerobic capacity through improvement in efficiency of the body's handling of lactate accumulation <sup>[18]</sup>. This in turn results in some physiological adaptations, all contributing, among which are increased blood volume, increased capillary density, and greater mitochondrial density, that lead to improved endurance performance. Importance is attributed to increased stroke volume in optimizing cardiovascular efficiency and endurance capacity <sup>[19,20]</sup>.

Several factors influence low plasma lactate levels during a competition: muscle fiber type, VO<sub>2</sub> max, running economy, and the ability to maintain high VO<sub>2</sub> max levels during races <sup>[21]</sup>. VO<sub>2</sub> max utilization strongly correlates with performances across various distances such as 5 km and 10 miles <sup>[22,23]</sup>. Endurance training also allows the muscles to use lactate, where its removal from circulation is improved <sup>[24]</sup>. After endurance training, there is generally a decrease in lactate production during a given workload because of increased mitochondrial size, number, and enzymatic activity <sup>[25]</sup>. Collectively, these

adaptations increase the energy production from mitochondrial respiration, thereby reducing lactate accumulation at a given intensity of work.

Running places considerable stress on the cardiovascular and musculoskeletal systems. Endurance athletes are usually characterized by an efficient oxygen transport system, increased heart volumes, and higher capillary densities <sup>[26]</sup>. These structural adaptations are thought to enhance cardiac pumping efficiency, leading to a greater stroke volume and cardiac output—factors determining maximal oxygen uptake <sup>[27]</sup>. Several mechanisms have been proposed for the increase in lactate threshold (LT) associated with endurance training, such as an increase in blood flow to the trained muscles, enhanced oxidative capacity of muscle cells, and changes in muscle fiber recruitment patterns that preferentially activate red and oxidative muscle fibers.

In this study, we measured blood lactate levels throughout extended running sessions and discovered that the pace rose with time. In light of the results presented, Tanaka et al. discovered that lactate readings allowed them to determine running speed at the onset of lactate accumulation, allowing them to predict running performance beforehand. That is, lactate readings can determine an individual's performance, regardless of whether he is a swimmer or a runner <sup>[28]</sup>. The long-distance runners' gastrocnemius muscle had a larger percentage of type I muscle fibers (79%) following resistance exercise training. Furthermore, the long-distance group had a considerably larger ( $p < 0.05$ ) oxidative potential as determined by the activity of the mitochondrial enzyme succinate dehydrogenase <sup>[29]</sup>. The capillary density in muscle tissue also showed a favorable correlation with this. Running can be made quicker, more efficient, and injury-free by improving running economy, stride mechanics, ground contact time, ground reaction force (GRF), and fatigue resistance <sup>[30]</sup>.

High running economy is physiologically necessary for distance running performance; in terms of biomechanics, this high economy results from the execution of optimal mechanical patterns that prevent inefficient movements while applying forces in the proper amount, direction, and timing. Veteran athletes have lower blood lactate concentrations, which can be explained by a lower proportion of type II muscle fibers, decreased lactate dehydrogenase activity, and increased oxidative enzyme activity. These factors help to clear lactate by reducing lactate production and carbohydrate utilization

[31].

Training just above the anaerobic threshold is known to increase aerobic capacity and anaerobic threshold levels <sup>[32]</sup>. Improvements in submaximal endurance performance occur mostly by increasing muscle oxidative capacity <sup>[33]</sup>. Changes in oxidative enzyme activity, rather than changes in maximal oxygen uptake, appear to influence running performance by endurance athletes and are implicated in substrate utilization during submaximal exercise <sup>[34,35]</sup>. Previous research pointed to a strong relationship between increases in blood or plasma lactate and performance in distance running. Additionally, it has been shown that endurance training lowers blood lactate levels at a given absolute or relative exercise intensity, which may indicate an increased reliance on fat metabolism and/or an improved aerobic breakdown of energy substrates

[36].

## 5. CONCLUSION

This work emphasizes the need of resistance training at the Lactate Threshold (LT) to improve endurance athletes' performance through time savings, heart rate, pacing, and lactate tolerance. Further, it underscores the importance of tailoring resistance training to an athlete's needs, in order to include not only physiological but also psychological factors in an effort to gain the

maximum gains in performance.

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