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The Effect of Endurance Training on Blood Lactate Concentration and Anaerobic Threshold in Bangladeshi Female Handball Athletes

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Abstract

Background. Endurance training has an essential role in improving the aerobic capacity and postponing the onset of exhaustion that can be beneficial to enhancing the performance. Handball involves both aerobic and anaerobic energy systems in the human body. Therefore, it becomes crucial to comprehend how training influences physiological variables such as anaerobic threshold and blood lactate concentration.

Objectives. The objective of this study was to examine the effect of an endurance training program on anaerobic threshold and blood lactate concentration in Bangladeshi female handball players.

Materials and methods. A total of sixty-four female athletes were selected using a purposive random sampling technique. The participants were randomly divided into two groups: 32 in the experimental group and 32 in the control group. A blood lactate analyzer, pulse oximeter, and treadmill test according to the Bruce protocol were used to assess blood lactate concentration, anaerobic threshold, resting heart rate, and maximum heart rate.

Results. The study observed a significant improvement in the experimental group, including a reduction in resting blood lactate concentration from 1.72 ± 0.15 mmol/L to 1.42 ± 0.12 mmol/L at the post-training phase. Additionally, there was an increase in onset of blood lactate accumulation from 4.51 ± 0.26 mmol/L to 4.73 ± 0.15 mmol/L, and an increase in speed at lactate threshold from 7.0 ± 0.0 km/h to 7.49 ± 0.19 km/h. It was also noted a considerable enhancement in the control group for variables such as resting heart rate, maximum heart rate, resting blood lactate concentration, and peak lactate concentration due to regular handball participation. Cohen's d was calculated to determine the effect size of endurance training. An independent t-test also revealed substantial differences between the experimental and control groups ($p < 0.05$).

Conclusions. The findings of this study indicate a significant effect of endurance training on the anaerobic threshold and blood lactate concentration in Bangladeshi female handball players.

Keywords: endurance training, blood lactate concentration, anaerobic threshold, onset of blood lactate accumulation, female handball players.

Introduction

Physical training is an integral component of athletic performance, particularly in sports that require a combination of aerobic endurance and anaerobic capacity for success (Reza et al., 2024). In handball, players engage in high-intensity intermittent efforts with short recovery breaks, making it essential for athletes to perform near or at their anaerobic threshold to excel. Blood lactate accumulation, commonly referred to as the onset of blood lactate accumulation (OBLA), is a key marker of the anaerobic threshold and serves as an important determinant of endurance capacity. It correlates with an athlete's ability to sustain prolonged high-intensity exercise without experiencing fatigue (Brooks, 1985; Faude et al., 2009).

Endurance training has been well-documented to enhance anaerobic capacity while reducing blood lactate levels during both submaximal and maximal exercise, leading to improved performance (Soyal et al., 2017; Sales et al., 2019). Monitoring blood lactate concentration across different phases of exercise testing helps identify the limits of each phase, allowing for the design of more effective training programs. Both lactate threshold and OBLA are highly responsive to endurance training. Researcher Ghosh (2004) argues that while lactate production decreases with training at a given

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work rate, the lactate threshold occurs later, enabling endurance athletes to sustain higher intensities before the onset of exhaustion.

Ball players require a balance of strength and power, which are crucial for both the aerobic and anaerobic components needed to execute powerful movements (Rahman & Sharma, 2023). Handball players require a balance of aerobic and anaerobic components to execute powerful actions while maintaining high anaerobic metabolism. Enhancing lactate clearance and improving the anaerobic threshold can significantly impact performance. Research shows that aerobic endurance training increases parameters such as lactate threshold speed, resting heart rate, and maximal heart rate, all of which are essential for sustaining prolonged performance (Denis et al., 1984; Poole et al., 2021).

Sustaining repeated high-intensity actions and recovering quickly are essential for handball players, as this helps minimize the risk of injury in athletes engaged in high-intensity sports (Islam et al., 2024). Effective performance depends on the ability to draw energy from both oxidative metabolism and anaerobic glycolysis, which requires a strong endurance base and the ability to resist fatigue, as evidenced by improvements in anaerobic threshold and blood lactate dynamics (Bishop et al., 2013; Meckel et al., 2009). The anaerobic threshold, defined as the exercise intensity at which lactate begins to accumulate in the blood, is a key performance parameter in endurance sports. Regular training above the lactate threshold helps increase the threshold, enabling athletes to perform more work before fatigue sets in, ultimately improving overall performance (Svedahl & MacIntosh, 2003).

In handball, where there is frequent alternation between aerobic and anaerobic energy systems, endurance training increases the anaerobic threshold and reduces blood lactate accumulation (Jacobs et al., 1986). Investigating the effects of endurance training on anaerobic threshold and blood lactate concentration in Bangladeshi female handball players offers valuable insights into optimizing training regimens. Despite the popularity of handball worldwide, there is limited scientific research on the physiological effects of specific training programs on South Asian handball players, particularly female athletes. This knowledge is essential for athletes and coaches aiming to improve anaerobic thresholds and regulate lactate accumulation during competition (Gordon & Scott, 2020; Kuk & McMillan, 2017).

This study investigates how an 8-week endurance training program affects blood lactate concentrations and anaerobic threshold in Bangladeshi female handball players. It focuses on key physiological variables, including lactate threshold speed (LT speed), onset of blood lactate accumulation (OBLA), and lactate threshold heart rate (LTHR). By providing new insights into endurance training adaptations in this unique athletic population, the study contributes to the limited research on female athletes in Bangladesh. The findings are expected to reveal important changes in resting lactate levels, OBLA, and lactate threshold performance, offering valuable information on improving athletic conditioning and performance.

Materials and Methods

Study Participants

A total of sixty-four female handball players were purposively selected from the Kushtia District of Khulna Division, Bangladesh. The participants were randomly assigned to an experimental group (EG), which performed specific aerobic exercises for endurance, and a control group (CG), which did not participate in these exercises. Table 1 illustrates the detailed characteristics of the subjects, including age, height, weight, and BMI. Before the trial began, participants were thoroughly informed about the study, including its benefits and any potential risks, ensuring they could make an informed decision about participation. All potential participants underwent a comprehensive medical examination by an attending physician to confirm their eligibility. All volunteers were in good health and deemed capable of safely undertaking the training regimen.

The research followed the ethical principles of the Declaration of Helsinki, ensuring that ethical standards were upheld throughout the investigation. This compliance reflects the study's commitment to the ethical treatment and respect of all participants. The Helsinki Declaration (2004) outlines pathways through which endurance training improves lactate regulation and performance, aiding in the development of optimized conditioning programs for these populations.

Study Organization

This study employed an experimental methodology using a two-group pretest-posttest design. The treatment group consisted of thirty-two participants who underwent an eight-week targeted endurance training program (table 2). The control group also comprised thirty-two participants who did not undergo this training, serving as the comparison group.

Table 1. Participants characteristics (Mean ± SD)

Characteristics	EXP (n = 32)	CON (n = 32)
Age(years)	16.44 ± 1.97	15.50 ± 1.83
Height(cm)	158.89 ± 6.92	158.24 ± 5.85
Weight(kg)	54.19 ± 6.21	55.41 ± 10.96
BMI (kg/m2)	21.73 ± 1.86	22.15 ± 3.78

Note: EXP is the group that practices endurance training, and CON control group refers to the groups did not receive endurance training. Values are reported as mean measurement with standard deviation (SD) the variability within each group.

All parameters were measured according to the standard protocols adopted in our laboratory. Prior to the program, a pre-test was conducted to evaluate all parameters for both groups. Following the trial, both groups participated in a standardized handball training program, which included technical drills, tactical exercises, and match play, conducted six days a week for eight weeks. The experimental group also underwent additional weekly endurance training sessions focused on increasing anaerobic threshold and cardiovascular endurance. These sessions ranged from high-intensity interval training (HIIT) to steady-state runs, as well as detailed anaerobic capacity-building exercises.

These protocols ensured that participants were in optimal condition for the experimental procedures. This systematic approach was designed to minimize variability and maintain adherence to ethical guidelines and scientific rigor throughout the study.

Table 2. Eight-week endurance training schedule for female handball players

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1st week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 10-15 min slow continuous run. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 3 sets of 2 laps handball field run at 70 % HR, 2-3 min rest between sets. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 2 sets of 3x30 sec reps with 30-sec break at 70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 20 min easy, off-road running. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest
2nd week	Endurance: 10 min continuous run at moderate speed. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Endurance: 3 sets of field run at 60-70 % HR, 2-3 min rest between sets. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: Pyramid training (20m, 40m, 60m, 80m, 120m) at 70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 20 min easy, off-road running. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest
3rd week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 15-20 min continuous run at moderate speed. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 2 sets of 3x40m slow/fast handball field runs at 60-70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: Pyramid training (20m, 40m, 60m, 80m, 120m) at 70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 20 min swimming or cycling. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest
4th week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 15 min continuous run at moderate speed. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: Pyramid training (10m, 30m, 50m, 80m, 110m) at 70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 3 sets of 3x45 sec reps with 60-sec break at 70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 20 min swimming or cycling. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest
5th week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 20 min continuous run. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 3 sets of 3 laps handball field run at 70 % HR, 2-3 min rest between sets. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 3 sets of 2x30 sec reps with 30-sec break at 75 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 30 min easy, off-road running. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest

Table 2 (continued)

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
6th week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 15 min continuous run at moderate speed. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 2 sets of 3x150m handball field runs at 75 % HR, 2-3 min rest between sets. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: Circuit training (6 stations, 30 sec each) at 75 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 30 min off-road running or cycling. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest
7th week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 20 min continuous run at moderate speed. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 3 sets of 3x20m slow/fast handball field runs at 60-70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: Pyramid training (20m, 40m, 60m, 80m, 120m) at 70 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 30 min swimming or cycling. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest
8th week	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 20 min continuous run at moderate speed. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: Pyramid training (10m, 30m, 50m, 80m, 110m) at 75 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Rec. act.	Warm-up: Jogging 10 min; Dynamic exercises. Endurance: 3 sets of 3x60 sec reps with 60-sec break at 75 % HR. Skill practice: 20 min. Cool down: Limbering down and stretching (5 min).	Run: 30 min swimming or cycling. Dynamic exercises. Skill practice: 20 min. Lead-up: Recreational game (10 min).	Rec. act.	Rest

Treadmill Protocol

The anaerobic threshold was measured using an incremental treadmill test on a motorized treadmill (Cardiovit Ergo-Spiro CS 200, Schiller AG, Switzerland) under controlled conditions. After a 10-minute warm-up at 50 % heart rate reserve, the test began at 6 km/h, with speed increasing by 0.5 km/h every 2 minutes until exhaustion. The treadmill incline was set at 0 %. Heart rate was monitored continuously, and blood lactate concentration was measured periodically to assess the anaerobic threshold. The onset of blood lactate accumulation (OBLA) was recorded, with threshold heart rate or blood lactate concentration used to determine the lactate threshold (Vachon et al., 1999; Ghosh, 2010). This protocol was used to evaluate the exercise capacity of participants.

Blood Lactate Measurement

At the end of each stage, blood lactate concentrations were measured using a portable lactate analyzer (Lactate Scout 4, EKF Diagnostics). After cleansing the fingertip with alcohol and blotting the first drop of blood, a capillary blood sample was collected using a lancet. A drop of blood was placed on a test strip in the analyzer, providing results in mmol/L within 10 seconds. This process was repeated at each stage to monitor lactate levels during the treadmill test. The anaerobic threshold was determined by the point of a marked increase in blood lactate, typically at the onset of blood lactate accumulation (OBLA, 4 mmol/L).

Cardiovascular Parameters

Resting heart rate was measured using an Apple Watch and a pulse oximetry heart rate monitor, with participants seated at rest for 10 minutes. Maximum heart rate was recorded at the point of exhaustion during the graded treadmill test.

Statistical Analysis

SPSS version 23.0 (IBM Corp., Armonk, NY) was used to analyze the data. Descriptive statistics were computed for each measured variable, expressed as mean ± standard deviation. Independent t-tests were conducted to assess differences between the experimental and control groups, while paired t-tests compared pre- and post-training values within each group. Statistical significance was set at $p < 0.05$.

The effect size was determined using Cohen's d method, which evaluates the strength of the training effect after significant changes were identified.

Results

Table 3. Paired sample t-test (experimental group)

Variables	RL (mmol/L)		OBLA (4 mmol/L)		PL 8km/h(mmol/L)	
Group	EXP		EXP		EXP	
Test	pre	post	pre	post	pre	post
Mean	1.72	1.42	4.51	4.73	12.66	13.17
SD	.15	.12	.26	.15	.749	.74
t value	10.12		-3.874		116.44	
Sig.(2-tailed)	.000		.001		.000	

Note: RL: Resting Blood Lactate; OBLA: Onset of Blood Lactate Accumulation; PL: Peak Blood Lactate

Table 3 shows that statistically significant changes at the 0.05 confidence level were observed in all variables for the experimental group (EXP) using a paired t-test analysis of pre- and post-training measurements. Resting Blood Lactate (mmol/L) showed a notable reduction, with the mean decreasing from 1.72 ± 0.15 before training to 1.42 ± 0.12 afterward ($t = 10.12$, $p < 0.05$). Although the change in Onset of Blood Lactate Accumulation (OBLA, 4 mmol/L) was modest, the mean increased slightly from 4.51 ± 0.26 to 4.73 ± 0.15, which was statistically significant ($t = -3.874$, $p < 0.05$). For Peak Blood Lactate (mmol/L), there was a significant increase, with the mean rising from 12.66 ± 0.749 to 13.17 ± 0.74 ($t = 116.44$, $p < 0.05$). These findings indicate meaningful physiological adaptations following the training.

Table 4 shows that, at the 0.05 confidence level, the paired t-test analysis of the experimental group revealed statistically significant improvements in all variables between pre- and post-training measurements.Lactate Threshold Speed (km/h) increased from 7.0 ± 0.0 to 7.41 ± 0.19, with a t-value of 11.59 ($p < 0.05$). Lactate Threshold Heart Rate (LTHR, bpm) rose from 136.15 ± 5.86 to 154.00 ± 9.57, showing a t-value of 15.05 ($p < 0.05$). Resting Heart Rate (HRrest, bpm) decreased from 62.96 ± 6.96 to 57.81 ± 4.76, with a t-value of 5.505 ($p < 0.05$). Maximum Heart Rate (HRmax, bpm) dropped from 195.15 ± 8.50 to 178.40 ± 5.56, with a t-value of 10.76 ($p < 0.05$). These results highlight significant cardiovascular improvements of the training.

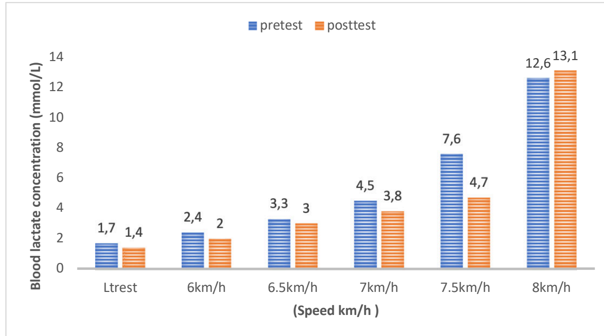

Fig. 1. Mean values of blood lactate concentration at various stages of incremental treadmill exercise and working load at every stage

This bar graph shows the blood lactate concentrations before and after the test at varying rates. The Anaerobic Threshold (AT), determined by the OBLA technique, is shown at 4 mmol/L. The blood lactate concentration is displayed in mmol/L on the y-axis, while the speeds are displayed on the x-axis in km/h. The lactate concentration level at which anaerobic threshold occurs is usually known as the OBLA (mmol/L).

Table 5. paired sample t test (control group)

Variables	RL (mmol/L)		OBLA (4 mmol/L)		Peak L 8km/h(mmol/L)	
Group	CON		CON		CON	
Test	pre	post	pre	post	pre	post
Mean	1.77	1.69	4.51	4.41	12.42	12.63
SD	.22	.22	.26	.21	1.12	.86
t value	2.693		1.86		-3.11	
Sig.2-tailed	.011		.072		.004	

Table 5 shows that the control group (CON) had mean resting blood lactate values of 1.77 ± 0.22 mmol/L before the test and 1.69 ± 0.22 mmol/L after the test. With a t-value of 2.693 ($p < 0.05$) and a minor difference between these averages, the intervention caused a significant decrease in resting blood lactate levels. The control group had mean OBLA values of 4.51 ± 0.26 mmol/L before the test and 4.41 ± 0.21 mmol/L after, with a t-value of 1.860 indicating no statistically significant change ($p > 0.05$) in OBLA levels, despite a slight decrease. The control group also had mean peak blood lactate values of 12.42 ± 1.12 mmol/L before the

Table 4. Paired sample t-test oflactate threshold speed, lactate threshold heart rate, resting heart rate, maximum heart rate of experimental group

Variables	LT speed(km/h)		LTHR(bpm)		HRrest(bpm)		HRmax(bpm)	
Group	EXP		EXP		EXP		EXP	
Test	pre	post	per	post	pre	post	pre	post
Mean	7.0	7.41	136.15	154.00	62.96	57.81	195.15	178.40
SD	0.0	.19	5.86	9.57	6.96	4.76	8.50	5.56
t value	11.59		15.05		5.505		10.76	
Sig.(2-tailed)	.000		.000		.000		.000	

Note: LT: Lactate Threshold; LTHR: Lactate Threshold Heart Rate; HR: Heart Rate

Table 6. Paired sample t-test oflactate threshold speed, lactate threshold heart rate, resting heart rate, maximum heart rate of control group

Variables	LT speed(km/h)		HR rest(bpm)		HR max(bpm)		LTHR(bpm)	
Group	CON		CON		CON		CON	
Test	pre	post	pre	post	pre	post	pre	post
Mean	6.92	6.95	69.62	64.09	192.40	185.78	131.12	135.81
SD	.18	.14	7.24	6.49	7.37	8.37	9.42	10.52
t value	1.0		5.53		6.11		-2.771	
Sig.2-tailed	.325		.000		.000		.009	

Note: LT: Lactate Threshold; LTHR: Lactate Threshold Heart Rate; HR: Heart Rate

test and 12.63 ± 0.86 mmol/L after. The t-value of -3.11 was statistically significant ($p < 0.05$), indicating a noteworthy change in peak lactate levels post-intervention, despite a modest increase in peak lactate.

Table 6 shows the control group (CON) had mean lactate threshold speed values of 6.92 ± 0.18 km/h before and 6.95 ± 0.14 km/h after the test. With a t-value of 1.0 ($p > 0.05$), the slight difference was not statistically significant, indicating no significant change in lactate threshold (LT) speed after the intervention. The group's mean resting heart rate (HRrest) increased from 64.09 ± 6.49 bpm to 69.62 ± 7.24 bpm, with a t-value of 5.53, significant at $p < 0.05$, suggesting improved cardiovascular fitness. Their maximum heart rate (HRmax) decreased from 192.40 ± 7.37 bpm to 185.78 ± 8.37 bpm, with a significant t-value of 6.11 ($p < 0.05$), reflecting a positive adaptation to the intervention. Lactate threshold heart rate (LTHR) increased from 131.12 ± 9.42 bpm to 135.81 ± 10.52 bpm, with a t-value of -2.771 ($p < 0.05$), indicating a statistically significant shift after the intervention.

This bar graph shows the blood lactate concentrations before and after the test at varying rates. The Anaerobic Threshold (AT), determined by the OBLA technique, is shown at 4 mmol/L. The blood lactate concentration is displayed in mmol/L on the y-axis, while the speeds are displayed on the x-axis in km/h. The lactate concentration level at which anaerobic threshold occurs is usually known as the OBLA (mmol/L).

Table 7 shows significant differences in all variables between the experimental (EXP) and control (CON) groups in the post-training analysis. The experimental group had a significantly higher OBLA (4.73 ± 0.15) compared to the control group (4.50 ± 0.26), with a substantial effect size

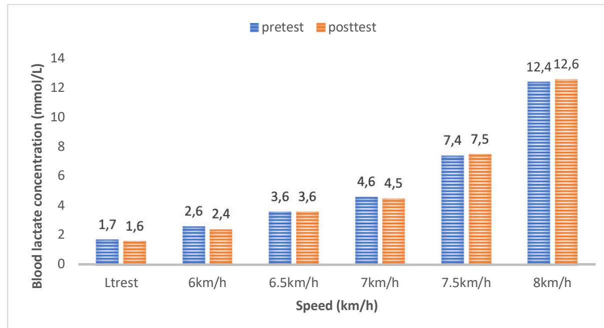

Fig. 2. Mean values of blood lactate concentration at various stages of incremental treadmill exercise and working load at every stage

(Cohen's d = 1.08, $p < 0.05$). Speed at lactate threshold (LT) was also significantly greater in the experimental group (7.40 ± 0.19) compared to the control group (6.95 ± 0.14), with a very large effect size (Cohen's d = 2.70, $p < 0.05$). For resting heart rate (HRrest), the experimental group showed a significant reduction (57.81 ± 4.76) compared to the control group (64.09 ± 6.49), indicating a training effect (Cohen's d = 1.10, $p < 0.05$). Maximum heart rate (HRmax) was significantly lower in the experimental group (178.40 ± 5.56) than in the control group (185.78 ± 8.37), with a notable training effect (Cohen's d = 1.04, $p < 0.05$). Lactate threshold heart rate (LTHR) was significantly higher in the experimental group (154.00 ± 9.57) compared to the control group (135.81 ± 10.52), with a large effect size (Cohen's d = 1.81, $p < 0.05$).

Table 7. Independent t test and Cohen's d test for measure of training effect post training

Variables	OBLA 4 mmol/L		LT speed (km/h)		HRrest(bpm)		HRmax(bpm)		LTHR(bpm)	
Group	EXP	CON	EXP	CON	EXP	CON	EXP	CON	EXP	CON
Test	post	post	post	post	post	post	post	post	post	post
Mean	4.73	4.50	7.40	6.95	57.81	64.09	178.40	185.78	154	135.81
SD	.15	.26	.19	.14	4.76	6.49	5.56	8.37	9.57	10.52
t value	4.162		10.35		-4.413		-4.147		7.229	
Sig .2-tailed	.000		.000		.000		.000		.000	
Cohen's d	1.08		2.70		1.10		1.04		1.81	
Effect Size	Large		Very large		Large (training effect)		Large (training effect)		Very large	

Discussion

In the experimental group, there was a significant decrease in RL from 1.72 ± 0.15 mmol/L to 1.42 ± 0.12 mmol/L ($p < .001$), with "t" value of 10.12 (Table 3). This decrease, with a Cohen's d of 1.08, indicates an improvement in aerobic ability which allows the body to process lactate more rapidly. This is in accord with the findings of Cao et al. (2021) and Favier et al. (1986) have ascribed it to increased oxygen use and mitochondrial efficiency. This lowering of RL is indicative to an improvement in the body's capacity to process lactate, this aspect which attributes a great deal for recovery and overall training response.

In the experimental group, OBLA slightly increased from 4.51 ± 0.26 mmol/L to 4.73 ± 0.15 mmol/L, with a t-value of 3.874 ($p < 0.05$). Although this increase was small, it reached statistical significance (Cohen's d = 1.08) and supported increased exercise intensities due to higher levels of lactate clearance in athletes. Ghosh (2004) highlighted that the athletes extending OBLA showed better performances even in endurance and intermittent sports, necessary for handball players. Studies by Losnegard et al. (2021), Ramadan & Mustafa (2023) confirm this conclusion as well, indicating that endurance training increase metabolic efficiency yield lactate production. According to Stanula et al. (2013) discussed byeven relatively modest improvements in lactate threshold permit higher work rates to be sustained over longer periods, a factor of critical importance for all aspects of handball matches.

There was also a small increase in the peak lactate levels reported at 12.66 ± 0.749 mmol/L and increased to 13.17 ± .74 mmol/L with t-value of 116.44. Despite improved lactate clearance, the increase in peak lactate during maximal exertion suggests enhanced anaerobic capacity, allowing athletes to produce more energy under high-intensity conditions. This is supported by Losnegard et al. (2021) and Cao et al. (2021), indicating that endurance training improves both aerobic and anaerobic systems. Sales et al. (2019) emphasized that anaerobic threshold improvements, like those seen in this study, are key to enhancing performance, especially during submaximal exercises.

Significant changes were observed in heart rate metrics, reflecting improved cardiovascular efficiency. Resting heart rate (HRrest) significantly decreased from 62.96 ± 6.96 bpm to 57.81 ± 4.76 bpm ($t = 5.505$, $p < 0.05$, Cohen's d = 1.10), while maximal heart rate (HRmax) dropped from 195.15 ± 8.50 bpm to 178.40 ± 5.56 bpm ($t = 10.76$, $p < 0.05$, $d = 1.04$). These reductions align with findings from Ghosh (2004) and Pennington (2015), indicating enhanced stroke volume and parasympathetic nervous system activity at rest. Additionally, the significant increase in lactate threshold heart rate (LTHR) ($t = 15.05$, $p < 0.05$, Cohen's d = 1.81) suggests that the athletes could sustain higher heart rates before reaching their lactate threshold, showing improved cardiovascular endurance. This is supported by Stefanov & Nejkov (2021), who reported that endurance training positively affects heart rate across different exercise intensities.

The control group (CON), which did not undergo specialized endurance training, showed limited physiological adaptations. RL levels decreased slightly from 1.77 ± 0.22 mmol/L to 1.69 ± 0.22 mmol/L, with a significant "t" value of 2.693 ($p < 0.05$), but changes in OBLA and LT speed were statistically non-significant. This suggests that regular handball practice, without structured endurance training, has a limited impact on improving lactate metabolism. The necessity for endurance training to achieve noticeable improvements in lactate metabolism was also emphasized by Svedahl & MacIntosh (2003) and Phillips et al. (1996).

The study demonstrates that endurance training significantly improved key metabolic and cardiovascular parameters in elite female handball players. Increases in OBLA, peak lactate, LTHR, and decreases in HRrest and HRmax point to enhanced aerobic and anaerobic capacity, allowing athletes to perform at higher intensities for longer periods. The large effect sizes (Cohen's d) across several variables emphasize the practical significance of these changes. These findings align with previous research, including that of Ramadan & Mustafa (2023), Losnegard et al. (2021), and Stanula et al. (2013), underscoring the importance of endurance training for competitive sports performance.

Conclusion

Eight weeks of endurance training program promotes large physiological changes in female handball players. Conclusions: An important finding of this study was a substantial reduction in resting blood lactate (RL), reflecting enhanced aerobic metabolism and lactate clearance. Greater peak blood lactate concentrations as well as an accompanying increase in OBLA and LT speeds indicate broader based tolerance for higher exercise workloads/intensities, indicative of improved anaerobic potential. This increase in cardiovascular efficiency was confirmed by larger changes between baseline and post follow-up for LTHR, HRmax and HRest. These results support the positive impact of structured endurance training to enhance aerobic and anaerobic performance among elite female athletes. The control group only saw a small improvement, which suggests periodized training is an essential aspect of performance enhancement in sports.

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Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Вплив тренування з розвитку витривалості на показники концентрації лактату в крові та анаеробного порогу у бангладешських спортсменок-гандболісток

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 9 с., 7 табл., 2 рис., 28 джерел.

Історія питання. Тренування з розвитку витривалості відіграє важливу роль у покращенні аеробних здібностей та відтермінуванні настання періоду виснаження, що може позитивно позначитися на підвищенні результативності. Гандбол передбачає залучення як аеробних, так і анаеробних енергетичних систем людського організму. Тому розуміння впливу тренувань на такі фізіологічні показники, як анаеробний поріг і концентрація лактату в крові, набуває ключового значення.

Мета дослідження. Це дослідження мало на меті вивчити вплив програми тренувань з розвитку витривалості на показники анаеробного порогу та концентрації лактату в крові у бангладешських гандболісток.

Матеріали та методи. Загалом було відібрано шістдесят чотири спортсменки із застосуванням методики цілеспрямованої випадкової вибірки. Учасниць було розподілено за методом рандомізації на дві групи: експериментальна група – 32 особи та контрольна група — 32 особи. З метою оцінки рівня концентрації лактату в крові, анаеробного порогу, частоти серцевих скорочень у стані спокою та максимальної частоти серцевих скорочень використовували аналізатор лактату в крові, пульсоксиметр та тредміл-тест за протоколом Брюса (“Bruce protocol”).

Результати. В рамках дослідження спостерігалося значне поліпшення показників в експериментальній групі, зокрема зниження рівня концентрації лактату в крові у стані спокою з 1,72 ± 0,15 ммоль/л до 1,42 ± 0,12 ммоль/л на посттренувальному етапі. Крім того, відзначено збільшення періоду щодо початку процесу накопичення концентрації лактату в крові з 4,51 ± 0,26 ммоль/л до 4,73 ± 0,15 ммоль/л, а також зростання швидкості лактатного порогу з 7,0 ± 0,0 км/год до 7,49 ± 0,19 км/год. Також у контрольній групі було відмічено суттєве покращення таких показників, як частота серцевих скорочень у стані спокою, максимальна частота серцевих скорочень, концентрація лактату в крові у стані спокою та пікова концентрація лактату завдяки регулярним заняттям гандболом. Для визначення розміру ефекту щодо виконання тренувань на витривалість було розраховано показник d Коена (Cohen’s d). Результати застосування t-критерію для незалежних вибірок виявили істотні відмінності між експериментальною та контрольною групами ($p < 0,05$).

Висновки. Отримані під час дослідження дані свідчать про значний вплив тренувань з розвитку витривалості на показники анаеробного порогу та концентрації лактату в крові у бангладешських гандболісток.

Ключові слова: тренування з розвитку витривалості, концентрація лактату в крові, анаеробний поріг, початок процесу накопичення концентрації лактату в крові, гандболістки.

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