The effect of extensive interval training at altitude on the physiological, aerobic, anaerobic and various blood parameters of athletes

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Abstract. In this research, it was aimed to compare the physiological performances of athletes at sea level, at high altitude and 8 days after returning back to sea level on the basis of certain blood parameters, pulse and blood pressure. 12 male athletes between the ages of 19 and 23 voluntarily participated in the research. The subjects were exposed to endurance training at high altitude and at sea level between 09.00 and 11.00 in the morning. The subjects' erythrocyte (RBC), leucocyte (WBC), haemoglobin (Hb), haematocrit (HCT), systolic blood pressure at rest (SBPR) and diastolic blood pressure at rest (DBPR), heart rate at rest (HRR), aerobic (20m shuttle run test) and anaerobic capacity (vertical jump) levels were tested at sea level, on the 15th day at high altitude (3120m) and 8 days after returning back to sea level. Statistical analysis comprised of t-test and the significance level of the results was accepted at ($P<0.05$). As a result of the research the following were determined: It can be said that high altitude trainings for fifteen days included in the annual training program of athletes can improve their performance.
Keywords: Sport, High Altitude, Physical and Physiological Properties.

1 Introduction

The effects of physical activities under various atmospheric conditions on performance take the attention of many researchers. In various researches, the effects of various atmospheric conditions on sportive performance have been studied and the changes both in the performance and in the body have been analyzed [10]. The first of these studies was conducted during 1968 Mexico Olympics. Later, the fact that athletes living at high altitude could show better performance in endurance sports contests at high altitude took the researchers' attention to the subject [2, 5, 10]. Generally, when they go to high altitude, people living at low altitudes show various physiological responses to deal with lack of oxygen and to prevent the fall in performance. These physiological responses appearing during training at sudden hypoxic (lack of oxygen) environment start to change as the body

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adapts to this environment in time; for example, tolerance to the training increases, physiological stress due to the training decreases and elevation adaptation develops [24]. As an athlete goes to higher altitude, if s/he hasn't been at that altitude before, s/he is exposed to various unfamiliar ecological factors like lack of oxygen, low air pressure, rays and different aerosols [3]. As one goes to higher altitude, partial pressure of the oxygen in the air breathed falls. This falling partial oxygen pressure damages oxygenation of blood. Insufficient oxygen saturation in blood reduces oxygen delivery to all the tissues in the body. The only way for the body to compensate this is to increase the ventilation value [23]. Elevation rise causes heart rate and incites the rise in cardiac output to increase blood circulation [16]. Cardiac output instantly rises about thirty percent but this rise turns to normal with the rise in the haematocrit value of blood [17]. It is known that physical performance is affected above 5000 feet and the effect increases as the altitude rises [14]. The cause of these changes stems from hypoxia. Altitude hypoxia might affect aerobic performance negatively, which is calculated as about 1% at every 100 meters after 1500 meters [20]. Acclimatization is adaptation to altitude and develops as short-term and long-term adaptations [18]. Trainings at high altitude lead to faster physiological changes than those at sea level, which is because of the fact that hypoxia at altitude puts the organism into stress and causes various short-term and long-term adaptations in the organism [6]. Acclimatization duration depends on elevation. For example, it is between 7 and 10 days at 9.000 feet, between 15 and 21 days at 12.000 feet and between 21 and 25 days at 15000 feet. These are only common estimations and the main factor is in fact individual differences [14]. The most important change in terms of adaptation to elevation is the increase in the capacity of oxygen delivery [9]. There is a direct relation between Hb content of blood and oxygen delivery to tissues. It has been established that Hb is inversely proportional to the fall in barometric pressure. An increase in Hb is a result of an increase in erythrocytes [8]. Upon raising elevation, because of a decrease in plasma volume (hemoconcentration), an increase appears in blood cells [5, 6, 12, 19, 24]. Due to dehydration through sweating and respiration while ascending high altitude, a decrease in blood plasma and an increase in HCT values occur [9]. An increase occurs in the myoglobin content of skeletal muscles together with a change in its characteristics and in the mitochondria number [7]. As one goes to high altitude, certain adaptations appear in human body in order to adapt to environmental hypoxia. For this reason, it was aimed in the research to determine the acute changes appearing in the aerobic strength, anaerobic strength, certain blood parameters, pulse and blood pressure of 12 male athletes before altitude, at altitude and after altitude.

2 Method

The participants of the study were voluntary athletes who had actively been engaged in various sports for average seven years. The subjects were 22±2.48 years old, with 183.58±7.01cm height and 74.26±12.63kg weight. RBC, WBC, Hb, HCT, SBPR, DBPR, HRR, Aerobic Strength (20m shuttle run test) and Anaerobic Strength (Vertical Jump Test) levels of the athletes were analyzed on the 15^{th} day of high altitude training and on the 8^{th} day of sea level training.

2.1 Training Program Conducted on the Subjects

The athletes were exposed to endurance training between 09.00 and 11.00 in the morning at high altitude and at sea level. During the training at high altitude, the atmospheric heat was between +12°C and +25°C while at sea level it was between +20°C and +32°C. Strict attention was paid to applying the same diet, schedule and sleeping routine at both high altitude and sea level.

Training

Aim: General Endurance

Method: Extensive İnterval Method

Loading: %40-%60

Set **:** 1-3

Exercises

1- 15min. jogging and warm-up
2- 250m. running
3- 1min. jogging
4- 400m. running
5- 1min. jogging
6- 650m. running
7- 1min. jogging
8- 900m. running
9- 1min. jogging
10- 650m. running
11- 1min. jogging
12- 400m. running
13- 1min. jogging
14- 250m. running
15- 15dk. Stretching and relaxation

2.2 Measurement Methods

2.2.1 Hematologic Measurements

The first measurements of blood RBC, WBC, Hb, HCT values were done at sea level at hospital laboratory by experts using a full automatic "Coulter Stks" hemogram as the subjects were seated at rest. The second measurements were conducted at high altitude at hospital laboratory by experts using a full automatic "Coulter Stks" hemogram as the subjects were seated at rest. The third measurements were conducted again at sea level at hospital laboratory by experts using a full automatic "Coulter Stks" hemogram as the subjects were seated at rest.

2.2.2 Measurement of Aerobic Capacity: 20m Shuttle run Test

The researcher had previously determined and marked the 20m distance to be covered during the tests at sea level and at high altitude. The subjects were asked to run 20m distance and back in the gymnasium having previously determined and marked. The running speed was checked at certain intervals with a tape that gave a signal sound. The subject was asked to start his run upon hearing the first signal and to have reached the other line by the time he heard the second signal. Upon hearing the second signal, he was asked to return back to the start line and the process continued as such with signals. The speed was slow at the beginning and increased every ten seconds. Whenever the subject passed every 20m line, it was recorded on a form [26].

2.2.3 Measurement of Heart Rate at Rest

Heart rates of the subjects at rest were measured with stethoscope (Auscultation) for 15sec. as seated when they rested and were recorded after multiplying them by four [15].

2.2.4 Measurement of Blood Pressure

The subjects' blood pressures are taken as seated. Stethoscope is placed right above the elbow joint over brachial artery (The middle point of the arm when the palm looks up). Sphygmomanometer is inflated rapidly until the pressure reaches 160 mmHg and then is deflated slowly until the first strong sound is heard. This is called the "Krotkoff" sound and it is heard when blood starts to pass the artery because the pressure on the artery has been reduced. This first "Krotkoff" sound is accepted as systolic blood pressure. The pressure reduction continues and the indicator is read when the beat sound suddenly decreases or disappears. This is accepted as diastolic blood pressure [18].

2.2.5 Measurement of Anaerobic Capacity: Vertical Jump Test

The athletes were asked to stand up on the rubber plate put on the floor and then the digital measurement tool showing the jump measurement was placed on their belly level and the belt was fastened while their arms were up. After the rope between the digital measurement tool and the rubber plate under his feet was stretched right in the middle of the feet and the measurement tool was reset, each athlete was asked to jump vertically by bending his knees and getting strength from his arms and to fall back on the rubber plate on the floor twice. The best score of the two jumps was recorded. Also, the body weights of the subjects were measured with precision scales and anaerobic strength calculation was done with the formula below [15, 4].

$P = (\sqrt{4.9}\ (\text{Weight})\ \sqrt{D})$

P = Power

D = Vertical Jump Distance**.**

3 Findings

According to the measurement results of the subjects at high altitude, a 2.16% increase was seen in their RBC measurements, a %2.90 increase was seen in their HCT measurements and a 4.58% increase was seen in their vertical jump measurements while a 6.47% decrease was seen in their 20m shuttle run test measurements. The differences in the subjects' RBC, HCT, 20m shuttle run test and vertical jump measurement values weren't statistically significant (P>0.05).

According to the measurement results of the subjects at high altitude, a %26.21 increase in WBC measurements, 5.35% in Hb measurements, a 10.02% increase in HRR measurements, a 24.56% increase in SBPR measurements and an 11.46% increase in DBPR measurements were found. The differences in the subjects' WBC, Hb, HRR, SBPR and DBPR measurement values were statistically significant (P<0.05).

According to the measurement results of the subjects at high altitude, a 7.40% decrease in RBC measurements, a 6.60% decrease in Hb measurements and a 3.27% decrease in HCT measurements were found while a 0.28% increase was seen in vertical jump measurements. The differences in the subjects' RBC, Hb, HCT and vertical jump measurement values weren't statistically significant (P>0.05).

Table 1. Analysis results

Variables		N	Mean	Std Deviation	X1-x2 %	t
Sea level-1	RBC	12	5,36750	,365762	2,16	0,424
Altitude (15th day)			5,48667	,350955		
Sea level-1	WBC	12	7,008333	1,4145082	26,21	0,001
Altitude			9,49667	1,5692838		
Sea level-1	Hb	12	15,917	,9173	5,35	0,003
Altitude			16,817	1,0152		
Sea level-1	HCT	12	48,108	2,9222	2,90	0,235
Altitude			49,542	2,8234		
Sea level-1	HRR	12	64,33	4,658	10,02	0,002
Altitude			71,50	5,266		
Sea level-1	SBPR	12	110,00	6,030	24,56	0,000
Altitude			145,83	10,836		
Sea level-1	DBPR	12	70,8333	6,33652	11,46	0,007
Altitude			80,0000	8,52803		
Sea level-1	Aerobic	12	46,350	3,9860	6,47	0,088
Altitude	Capacity		43,350	4,2507		
Sea level-1	Anaerobic	12	110,92	18,928	4,58	0,531
Altitude	Capacity		116,25	21,959		

Table 2. Analysis results

Variables		N	Mean	Std Deviation	X1-x2 %	t
Altitude	RBC	12	5,48667	,350955	7,40	0,121
Sea level-2 (8th day)			5,08833	,780837		
Altitude	WBC	12	9,491667	1,5692838	26,35	0,002
Sea level-2			6,995833	1,9337268		
Altitude	Hb	12	16,817	1,0152	6,60	0,14
Sea level-2			15,708	1,0238		
Altitude	HCT	12	49,542	2,8234	3,27	0,220
Sea level-2			47,925	3,4168		
Altitude	HRR	12	71,50	5,266	11,88	0,000
Sea level-2			63,00	4,553		
Altitude	SBPR	12	145,83	10,836	26,85	0,000
Sea level-2			106,67	6,513		
Altitude	DBPR	12	80,0000	8,52803	14,58	0,001
Sea level-2			68,3333	5,77350		
Altitude	Aerobic	12	43,350	4,2507	14,68	0,000
Sea level-2	Capacity		50,817	4,2893		
Altitude	Anaerobic	12	116,25	21,959	0,28	0,917
Sea level-2	Capacity		116,58	22,516		

According to the measurement results of the subjects at high altitude, a 26.35% decrease in WBC measurements, a 11.88% decrease in HRR measurements, a 26.85% decrease in SBPR measurements and a 14.58% decrease in DBPR measurements were found while a 14.68% increase was determined in 20m shuttle run test test measurements. The differences in the subjects' WBC, HRR, SBPR, DBPR and 20m shuttle run test measurement values were statistically significant ($P<0.05$).

The differences between the RBC, WBC, Hb, HCT, HRR, SBPR, DBPR and anaerobic measurement values of the subjects before going to high altitude and 8 days after turning back to sea level weren't found to be statistically significant ($P>0.05$). Only the differences between the aerobic measurement values of the subjects were found to be statistically significant ($P<0.05$). In the measurements shown in Table-3, it was determined that a 8.77% significant increase occurred in the aerobic capacity 8 days after returning back from high altitude and a 4.85% increase happened in the anaerobic capacity, but this increase was statistically insignificant.

Table 3. Analysis results

Variables		N	Mean	Std Deviation	X1-x2 %	t
Sea level-1	RBC	12	5,36750	,365765	5,34	0,274
Sea level-2			5,08833	,780837		
Sea level-1	WBC	12	7,008333	1,4145082	0,14	0,986
Sea level-2			6,995833	1,9337268		
Sea level-1	Hb	12	15,917	,9173	1,31	0,605
Sea level-2			15,708	1,0238		
Sea level-1	HCT	12	48,108	2,9222	0,37	0,889
Sea level-2			47,925	3,4168		
Sea level-1	HRR	12	64,33	4,658	2,06	0,486
Sea level-2			63,00	4,553		
Sea level-1	SBPR	12	110,00	6,030	3,02	0,207
Sea level-2			106,67	6,513		
Sea level-1	DBPR	12	70,8333	6,33652	3,58	0,323
Sea level-2			68,3333	5,77350		
Sea level-1	Aerobic	12	46,350	3,9860	8,77	0,015
Sea level-2	Capacity		50,817	4,2893		
Sea level-1	Anaerobic	12	110,92	18,928	4,85	0,521
Sea level-2	Capacity		116,58	22,516		

4 Discussion and Conclusion

As a result of the study, during the first measurements at sea level, the RBC values were found 5.36±0.36million/mm^3 and, during the second measurements at high altitude, they were found 5.48±0.35million/mm^3. The increase in the RBC values was determined to be statistically insignificant (P>0.05). During the third measurements 8 days after returning back to sea level, the RBC values were found 5.08±0.78 million/mm^3. Accordingly, comparing the RBC values at the first measurements before going to high altitude and at the third measurements 8 days after returning back to sea level, a 5.34% fall was seen; however, this fall was determined to be statistically insignificant (P>0.05). Despite insignificant findings of the study, the RBC values at high altitude were still higher than those at sea level. It is thought that the duration at high altitude might have caused an increase in RBC numbers in blood. Since the oxygen rate will increase due to the rise in the RBC numbers, this might have affected the performance of the athletes positively. The test results confirm that the RBC number decreased at sea level. Sayan et al. [28] determined in their study on 14 athletes that the mean RBC values obtained during their measurements before going to high altitude (850 m) was 5.03±0.55x1000 mm^3 and it was 4.68±0.48x1000 mm^3 during the second measurement on the fifth day at high altitude (1800 m). Robert et al. (30) determined that during the first measurements before going to high altitude the total red cell volume was ml/kg.29.2±4.0, while it was ml/kg.31.5±4.1 during the second measurements on the twenty-eighth day at high altitude.

During the first measurements at sea level, the subjects' mean WBC values was found 7.00 ±1.41bin/mm^3 while it was 9.49 ±1.56bin/mm^3 during the second measurements at high altitude. The increase between these two measurements was found to be statistically significant (P<0.05). During the third measurements 8 days after returning back to sea level, the WBC values were found 6.99±1.93bin/mm^3. As seen in Graph 2, the decrease in the WBC values between the second measurements at high altitude and the third 8 days after returning back to sea level is statistically significant (P<0.05). Sayan et al. [28]

determined in their study on 14 athletes that the mean WBC values obtained during their measurements before going to high altitude (850 m) was 6.88±1.39x1000 mm^3 and it was 7.17±1.01x1000 mm^3 during the second measurement on the fifth day at high altitude (1800 m). Robert et al. [30] determined that during the first measurements before going to high altitude the total blood volume was ml/kg. 83.7±8.5, while it was ml/kg.31.5±4.1 during the second measurements on the twenty-eighth day at high altitude. Fox et al. [14] stated that training at high altitude causes higher rate of physiological changes compared with the one at sea level and added that this is because the fact that altitude hypoxia leads to a force causing physiological changes similar to those caused by physical training. It is thought that different factors of altitude are effective in the decrease in the RBC and WBC values at sea level.

During the first measurements of the subjects' mean Hb values at sea level was found 15.91 ±0.91g/100ml, while it was 16.81 ±1.01g/100ml at high altitude. The differences between the values at high altitude and sea level were found statistically significant ($P<0.05$). A 5.35% increase was seen as one went to high altitude compared with sea level. When climbed down to sea level, during the measurements on the 8th day at sea level, Hb values were found 15.70 ±1.02g/100ml and a 6.60% decrease was determined. Özcan [21], found in his study in 1990 conducted on 16 athletes at a ski centre on Mount Erciyes in the city of Kayseri at 2150 m that, prior to the fortnight camping, their mean haemoglobin amount 14.9 ±0.3g/100ml whereas it became 15.5 ±0.2g/100ml after the camping. In Doğar's [9] research, mean haemoglobin values was 16.30 ±0.61g/100ml in Erzurum, while it was 14.48 ±0.48g/100ml in İzmir–3 measurement and the difference between the measurements was statistically significant ($P<0.01$). It is seen that Özcan and Doğar's studies confirm this study's Hb values. Dante and Javier [29], determined in their study conducted on 11 subjects living at high altitude (4540m) that the subjects' Hb value was 18.5 ±1.8g/dL in their first measurements at 4540m, whereas it was 13.5 ±0.81g/dL in their second measurement done two years after the subjects came to sea level.

The subjects mean HCT values was found %48.10±2.92 at sea level, whereas it was %49.54 ±2.82 at high altitude. The change between these two values wasn't found statistically significant ($P>0.05$). It was determined during measurements that as the athletes went to high altitude, their HCT rate increased 2.90%. During the measurements on the 8^{th} day at sea level, HCT measurement values were %47.92± 3.41 and a 3.27% decrease was found in the HCT values. Ergen and Açıkada [1] state that an increase in haematocrit values might occur during long-term adaptation to high altitude. Özcan [21], found in his study that the mean haematocrit amount prior to a fortnight camping at high altitude was %45.7 ±0.3 whereas after the fortnight camping period the mean became %47. ±40.7. The increase was found statistically significant ($P<0.05$). Dante and Javier [29], determined in their study conducted on 11 subjects living at high altitude (4540 m) that the subjects' Hct value was 55.4 ±5.03 in their first measurements at 4540 m, whereas it was 41.9 ±2.8 in their second measurement done two years after the subjects came to sea level.

During the measurements at sea level, the subjects' mean HRR values was found 64.33 ±4.65at/min, whereas it was found 71.50 ±5.26at/min. during the measurements at high altitude. The change between these two values was found statistically significant ($P<0.05$). When the athletes climbed high altitude, a 10.02% increase was found in their heart rate per minute. The measurements on the 8^{th} day after returning back to sea level showed that their HRR values were 63.00±4.55at/min. and the difference between the two values was found statistically significant. A 11.88% fall was determined at sea level. The HRR means in this study are supported by the values put forward in the literature. In Zorba's [25] study, while the subjects' HRR mean was 70.4 ±8. 9at/min. before altitude, it rose to 76.06 ±8.6 at/min. at high altitude and fell down to 68.8 ±7.8at/min. after altitude. One of the most important reasons for this is the decrease in the oxygen pressure as altitude rises. Savaş et al. [22], as a result of their interval training at 1890m, found that while the HRR was 74.5±5.59at/min. before altitude, it fell down to 73.0 ±3.72at/min. after the 8-week training. Frisoncho et al. [15] determined that heart rate values are less at lower altitudes compared with higher altitudes in Peru and America. Some other researchers found that heart rate rises 50% at high altitude. Ergen [13] states that tissues try to get enough blood through the increase in respiration frequency and circulation system heart rate at altitude.

The subjects' mean SBPR values were found 110.00±6.03mmHg at sea level measurements, while they were found 145.83±10.83mmHg at high altitude measurements. The difference between the two values was found statistically significant ($P<0.05$). When the athletes climbed high altitude, a %24.56mmHg increase was found in their SBPR values. During the measurements on the 8th day after returning back to sea level, the SBPR values were determined to be 106.67±6.51mmHg. The difference between the two values was determined to be statistically significant ($P<0.05$). When the athletes descended to sea level, a %26.85mmHg fall was seen in their SBPR values. The literature supports this study. Zorba [25], found in his research on 15 male athletes of METU Physical Training and Sports Department that their systolic blood pressure was 111.5±6.6mmHg before altitude, 117.0 ±5.02mmHg at altitude and 116.26±7.51mmHg after altitude. Doğar [9] found in his study that the mean SBPR values was 111.87 ±4.16mmHg in Erzurum, 110.00 ±6.32mmHg in İzmir-1 measurements, 107.12±5.72mmHg in İzmir-2 measurements and 114.00±5.93mmHg in İzmir-3 measurements. The change was found statistically significant.

The subjects' mean DBPR values were found 70.83±6.33mmHg at sea level measurements, while they were found 80.00±8.52mmHg at high altitude measurements. The difference between the two values was found statistically significant ($P<0.05$). When the athletes climbed high altitude, a %11.46mmHg increase was found in their DBPR values. During the measurements on the 8th day after returning back to sea level, the DBPR values were determined to be 68.33±5.77mmHg. The difference between the two values was determined to be statistically significant ($P<0.05$). When the athletes descended to sea level, a %14.58mmHg fall was seen in their DBPR values. The literature supports this study. Zorba (25), found in his research on 15 male athletes of METU Physical Training and Sports Department that their diastolic blood pressure was 67.73±10.8mmHg before altitude, 67.5 ±10.2mmHg at altitude and 70.13±8.79mmHg after altitude. Doğru [11] concludes as a result of his studies that high altitude has a positive effect on respiration and cardiovascular system.

The subjects' mean aerobic capacity values were found 46.35±3.98ml/kg/min at sea level measurements, while they were found 43.35±4.25ml/kg/min at high altitude measurements. The difference between the two values wasn't found statistically significant. When the athletes climbed high altitude, a 6.47% decrease was found in their aerobic capacity values. During the measurements on the 8th day after returning back to sea level, the aerobic capacity values were determined to be 50.81±4.28ml/kg/min. The difference between the two values was determined to be statistically significant. When the athletes descended to sea level, a 14.68% increase was seen in their aerobic capacity values. The literature supports this study.

Fox et al. [14] state as a result of their study that capability to do physical work over 1527m (5000feet) decreases depending on hypoxia and high altitude especially affects aerobic activities. Zorba [25] found in his research on 15 male athletes of METU Physical Training and Sports Department that found in his research on the aerobic capacities of athletes of METU Physical Training and Sports Department that the subjects' aerobic capacity values before and after altitude showed significant differences. Doğar [9] found in his study on 8 athletes that the subjects' mean maximal VO2 values were 58.85±2.75ml/kg/min in Erzurum and 62.81 ±3.19ml/kg/min in the measurements one the

8th day of the camp in İzmir. The increase was found to be statistically insignificant.

The subjects' mean anaerobic capacity values were found 110.92 ±18.92 kg-m/sec at sea level measurements, while they were found 116.25 ±21.95kg-m/sec at high altitude measurements. The difference between the two values wasn't found statistically significant. When the athletes climbed high altitude, a 4.58% increase was found in their anaerobic capacity values. During the measurements on the 8th day after returning back to sea level, the anaerobic capacity values were determined to be 116.58 ±22.51kg-m/sec. The difference between the two values was determined to be statistically insignificant. When the athletes descended to sea level, a 4.85% increase was seen in their anaerobic capacity values. Fox et al. [14] found in their study on 26 students with average age of 15 that the mean anaerobic strength was 69.6 kg-m/sec. In the same research, the fact that the mean anaerobic strength of male athletes between 20 and 30 years of age was 140-175 kg-m/sec was considered mediocre, whereas 176-210 kg-m/sec was considered good. Baydil [27] determined in his study on 32 subjects in 2005 that the mean anaerobic strength of the subjects during the first measurement before ascending to high altitude (730m) was 136.58 ±4.76kg-m/sec, while it was 140.25 ±3.75kg-m/sec during the measurement at high altitude (1850m). The information gathered through literature review supports this study in that it shows that training at high altitude doesn't have a positive effect on anaerobic capacity.

As a result of the research the following were determined: athletes making an effort at high altitude should be supported with vitamins and minerals, should do regular sleeping and resting, and exercises that will cause lactic acid accumulation shouldn't be done on the first days. Training at high altitude especially affects aerobic activities. As altitude rises, the physiological and hematologic differences arising from the decrease in oxygen level directly affects the athletes' performance. Accordingly, it can be said that high altitude trainings for fifteen days included in the annual training program of athletes can improve their performance.

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