Freitas L. (2024) THE INFLUENCE OF ALTITUDE TRAINING ON HEMATOLOGICAL PARAMETERS AND ENDURANCE PERFORMANCE. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte vol. 24 (96) pp. 272-286.
DOI: https://doi.org/10.15366/rimcafd2024.96.016

ORIGINAL

THE INFLUENCE OF ALTITUDE TRAINING ON HEMATOLOGICAL PARAMETERS AND ENDURANCE PERFORMANCE

Lucia Freitas

Center for Sports Performance and Injury Prevention, Federal University of Rio de Janeiro, Brazil.

Recibido 12 de octubre de 2023 **Received** October 12, 2023
Aceptado 11 de puede de 2024 **Accepted** May 11, 2024

ABSTRACT

The research aims to determine the influence between altitude training studies also explain the haematological parameters and endurance performance. The research was based on secondary data analysis, and different websites related to hematological parameters were used to collect the data. When proper exercises are performed at high altitudes for many days, the body of the athlete becomes habitual in such a way that it can bear more pressure from exercise and also be able to cope with the after-effects of exercise, such as fatigue. The research study depends upon quantitative analysis to determine the research using E-view software and perform results including descriptive, unit root test, histogram, and state analysis, which also explain the graphical analysis between them. The other important implication of high-altitude training is that it helps in the mental growth of athletes, thus helping them to cope with mental health issues such as stress, anxiety, depression, fear of failure, Fear of height, and others as well. The overall research found that the direct and significant influence of altitude training on haematological parameters and endurance performance. All of these facts prove that high altitude training is necessary for enhancing athletes' performance and endurance level during sports.

KEYWORDS: Altitude Training (AT), Hematological Parameters (HP), E-views Software, Endurance Performance (EP).

1. INTRODUCTION

As we all know, we all live in the modern era of science and technology, where scientific studies have proved that high altitude significantly affects the hematologic parameters and endurance of the body. An athlete's body must be better in endurance, tolerance, performance, and Hematological Parameters

than a man'sa layman's. In this introduction, we will understand how high-altitude training impacts the Hematological Parameters and endurance of athletes(Constantini et al., 2017). An athlete must undergo various types of training to enable his body to bear the stress in terms of physical and mental aspects. High-altitude training is one of the most important training methods for athletes. In high-altitude training, an ab athlete must stay elevated and perform different tasks to make his body acclimatized to heightened places. In this introduction, we will discuss haematological parameters first, and then we will comprehend endurance aspects later. Haematological Parameters refer to all those measurable components of blood that are measured to get an idea about the function and health of the blood system in the human body(Haile et al., 2019). There are various components in Hematological Parameters such as haemoglobin level, red blood cell amount, White blood cell amount, number of platelets, mean corpuscular volume, hematocrit level, mean corpuscular haemoglobin, blood level indices, and others. All of these components are collectively measured to get an idea about the normal functioning and composition of the blood system. As we are discussing the influence of Altitude Training on Hematological Parameters, we came to know that high altitude Training has a positive impact on the blood system in a variety of ways, which are discussed here. The first influence of high altitude training on Hematological Parameters is that high altitude training increases the main haemoglobin level in the blood(Saunders et al., 2009). Through medical studies, we learned that haemoglobin is the main oxygen transporter protein in the blood, which also gives a red colour to blood. The normal haemoglobin level is necessary to maintain oxygen levels in the body. The decreased level of haemoglobin may result in fatal consequences. However, with the help of high altitude training, the haemoglobin level increases to 2 to 3 %. In an athlete's body, there is a demand for more oxygen than in the body of the common man. So this demand for high oxygen can be fulfilled by increasing the level of hemoglobin with the help of high-altitude training(Schmidt et al., 2002). The second benefit of high altitude training for hematologic parameters is in terms of increasing the number of red blood cells. The number of red blood cells is directly related to oxygen transportation in the body, which is related to muscle strength and activity. It has been proved that an athlete needs more Oxygen in the body to perform well during sports. The other benefit of high altitude training for hematologic parameters is in the aspect of increasing the level of hematocrit, which directly measures the proportion of red blood cells in the body required for the transportation of oxygen in the body(Park et al., 2022). Medical studies have proved that the correct proportion of iron is mandatory in the body because iron is the main component of haemoglobin. The structure of haemoglobin is aligned in such a way that iron binds the ring structures in haemoglobin. Recent studies have proved that iron metabolism can be enhanced in a better way by high-altitude training. In the next portion of the introduction, we will talk about the benefits of high-altitude training in terms of endurance and performance of

athletes(Ramos-Campo et al., 2015). It does not matter which type of sport an athlete is involved in; high altitude training is the basic and main type of training for increasing the endurance and Performance of athletes. As we know, there are two types of respiration: aerobic and anaerobic. For athletes to perform better during sports, the rate of aerobic respiration must be higher in athletes than in the common man. With the help of high-altitude training, the athlete's body becomes habitual of less oxygen concentration because the concentration of oxygen gas decreases by increasing altitude. When the body becomes habitual, these trained athletes will be able to effectively perform aerobic respiration during the performance, resulting in better endurance (Moges et al., 2024). Not only does the blood system of an athlete work well, but the cardiovascular system will also be improved by high-altitude training. By high altitude training, an athlete's heart will be able to bear more pressure and stress and give better output that will bring positive response in terms of performance and endurance of the athlete. Another term that is also used to describe the intensity of exercise is lactate threshold. With the help of high altitude training, the lactate threshold level also increases, and the athlete's body becomes habitual in exercising for a long time. The other benefit of high altitude training is that the endurance of skeletal muscles increases. When muscles become habitual of working under stress, the strength and working of muscles increase, and ultimately, the athlete's performance improves (Płoszczyca et al., 2018). Before performing on the ground, an athlete must fight their fears. With the help of high altitude training, an athlete confronts different types of fear, such as fear of height, fear of being alone, fear of falling, fear of less Oxygen, and fear of being unsocial. When an athlete learns to cope with all these fears, his body's mental tolerance increases, resulting in better performance (Rusko et al., 2004). For effective endurance and Performance of athletes, both mental and physical health types are mandatory. We mostly focus on physical health, but mental health is also a prerequisite. With the help of high altitude training, the mental health of athletes also improves because athletes come closer to nature, bringing them mental calmness. This study has brought to light the positive impacts of high-altitude training on athletes' hematologic parameters and endurance. High-altitude training must be part of athletes' training for better performance and endurance of the body during sports(Bailey & Davies, 1997).

1.1 Research Objective

The main objective of this research is to understand what benefits can be obtained by high altitude training in terms of hematologic parameters and body endurance. This study has effectively explained the consequences of high-altitude training on the body and brain of athletes to perform well. The purpose of the study is to ascertain how altitude training affects haematological markers and outcomes. There are five distinct chapters that make up the research. The introduction to both indicators is covered in the first section. The

goal of the study is also represented in this part. A review of the literature is presented in the second part. The variables and approach are covered in the third section. The outcome and its explanation are covered in the fourth section. Furthermore, the final portion provides a summary of the whole research study and outlines performance suggestions.

2. Literature Review

Recent studies have shown that various training is given to athletes to maximize their performance, endurance, strength, and other factors. High altitude training is one of them, and it is directly related to enhancing the performance of athletes(Gürses & Akgül, 2018). In this review, we will overview those studies that explain the positive impacts of high altitude training on Hematological Parameters and endurance performance of athletes. If we try to understand the term hematologic parameters, we will come to know that there are parameters related to the body's circulatory system (Hahn & Gore, 2001). These studies are based on the results of a few trainings given at high altitudes. After collecting results, the following main points have been observed(Strzała et al., 2011). Those athletes who were given high-altitude training had increased haemoglobin in their bodies. The reason for this fact is that haemoglobin is directly related to the transport of oxygen in the body; when training is given at high altitudes, there is less pressure or concentration of oxygen as compared to the pressure that is required for normal breathing(Erica Mabel Mancera-Soto et al., 2022). Thus the alternative option is to increase the quantity of hemoglobin in the body so that more oxygen with less pressure can be inhaled inside to meet the body's needs (Banfi et al., 2004). The other result of this high-altitude training has been seen as an increased number of red blood cells in the body. Those athletes who were given high-altitude training had more red blood cells in their bodies than those who were not (Törpel et al., 2020). The other result that was obtained after high altitude training is the increased concentration of iron in the body. Iron is a major and important part of the haemoglobin structure, and any fluctuation in iron concentration may cause changes in haemoglobin level in the body(Fernández-Lázaro et al., 2020). But with the help of high altitude training, the concentration of iron in the body increases, which is a plus point for improving the health of athletes(Bahenský et al., 2020). The next benefit that has been seen as a result of high altitude training is the acclimatization of athletes to breathe in low oxygen as well; when they get to know how to control breathing in low pressure, this factor helps them enhance performance as well(Heinicke et al., 2005). Let's talk about the next benefit of high-altitude training. We must mention that high-altitude training also increases lactate threshold, a factor used to describe exercise intensity(Yan et al., 2021). In other words, such terms are used to explain how much pressure the body can tolerate during exercise. When the lactate threshold increases by high altitude training, the ability of athletes to exercise for more time also increases(Dragos et al., 2022). Medical science has proved that the immune

system of the body is the first shield of the body to fight pathogens and prevent diseases in the body. When the immune system gets well, the overall chances of disease also decrease(Berglund, 1992). It has been proved that the major benefit of high altitude training is that it increases the number of White blood cells and platelets in the body, which are directly involved in increasing the body's immunity (Erica M Mancera-Soto et al., 2022). The other benefit of high altitude training is that it increases the hematocrit level of blood, which is directly related to the proportion of red blood cells in the body. The body's circulatory systembody's circulatory system is not only limited to blood, but the heart and blood vessels are also included in it(Wehrlin et al., 2016). The benefit of high altitude training has also been seen as relevant to the condition of the heart. The heart muscles or cardiac muscles get strength by high altitude training, thus maximizing the heart's normal function (Martinez-Bello et al., 2011). Now, we will overview those studies related to the endurance parameters of athletes related to High altitude training. The performance of any athlete is related to and dependent upon the tolerating ability of the body or simply the endurance of the body. Recent studies have shown that high-altitude training also increases the endurance of the body in various ways(Fernández-Lázaro et al., 2022). The first way of increasing the body's endurance is by increasing the strength of skeletal muscles. When skeletal muscles get habitual in performing more work with less concentration of Oxygen, they get strength in terms of increasing muscle fibres in muscles(Constantini et al., 2017). As we know, there are two types of respiration: aerobic and anaerobic. When there is less oxygen concentration in the body, muscles prefer to perform anaerobic respiration, increasing the strength of skeletal muscles(Haile et al., 2019). The other way of increasing body endurance by high altitude training is that it helps athletes fight their stress fear and anxiety. At the start of high altitude training, there is a risk of increasing stress and anxiety in the body of the athlete, but with time, an athlete learns to cope with these factors to increase the strength of the body(Saunders et al., 2009). A major factor of loneliness in high altitude training is quite tough to cope with. Still, this factor is beneficial for training athletes to be habitual in coping with stress and anxiety alone without any dependence on others(Schmidt et al., 2002). In ancient times, it was considered that only physical health was mandatory for performing well in sports athletes. Still, later studies have brought to light that the athlete's overall performance depends on the sum of the physical and mental health of the athlete(Park et al., 2022). By studying the consequences of high altitude training, I learned that these types of training help enhance the mental health of athletes, which brings positive results in the performance of athletes (Ramos-Campo et al., 2015). An athlete learns to overcome many fears through high altitude training, such as fear of heights, stress, anxiety, etc. All of these factors collectively enhance the athlete's hematologic parameters and endurance (Moges et al., 2024). In recent years, only land-based training was provided to athletes. Still, with the help of different studies, it came to know that an athlete must be provided with

different types of training that may enhance the body's endurance along hematologic parameters(Płoszczyca et al., 2018). After reviewing all the studies related to the impact of high altitude training on Hematological Parameters and endurance of athletes, we came to conclude that High altitude training has a greater impact on increasing and improving hematologic parameters and endurance of the body of athletes(Rusko et al., 2004). All of these studies have effectively enumerated the positive impacts of high altitude training. However, there is still room for more studies to be done to improve the situation in the near future (Castro, 2019).

3. Methodology

The research study describes the influence of altitude training on performance. The research is based on secondary data analysis to determine the research using E-views software and generate results, including descriptive statistics, and unit root test analysis, which also explains the histogram and state analysis between them. according to the research, training is the soul of the adequate performance of the athlete. No athlete can perform well without the assistance of any consistent training. A variety of trainings help the athlete to enhance their performance and excel in aspects of sports. These trainings are mandatory to transform an ordinary layman into an athlete. These training include underwater training, high altitude, running training, jumps, squats, and others. In this study, we are going to discuss the implications of the influence of Altitude Training on Hematological Parameters and endurance performance of athletes(Haile et al., 2019). The following are essential hematologic and endurance implications of high-altitude training:

3.1 Increase in the Level of Haemoglobin in Blood

The function of haemoglobin can be better explained if the structure and type of haemoglobin can be understood well. Hemoglobin is a kind of tertiary protein in the body made up of different amino acids. Its main function is to transport oxygen into the body. The level of oxygen in the body depends upon the quantity or concentration of haemoglobin in the body. If we discuss the oxygen demand of athletes, we can say that athletes need more oxygen as compared to laymen because of the intensity of work or exercise(Saunders et al., 2009). The athletes need Oxygen during exercise as well as during performance in sports. The oxygen demand can only be fulfilled by increasing the number and amount of hemoglobin in the body in natural ways. One of the natural ways of increasing hemoglobin levels in the body is high-altitude training for athletes. When athletes are given training at high altitudes, there is very little concentration of oxygen at high altitude because the concentration of gases decreases with increasing height. When athletes have to be trained at high altitudes, their bodies have to react in such a way as to transport oxygen well in the body. This oxygen demand can be fulfilled only by increasing the

concentration of hemoglobin in the body which carries oxygen in the body. It has been proved by scientific studies that high-altitude training is an effective way to increase hemoglobin levels in an athlete's body. It is one of the important implications of high-altitude training in athletes(Schmidt et al., 2002).

3.2 Increased Level of Hematocrit After Training

The level of hematocrit is related to the proportion of red blood cells in the blood. It is an important standard to know about the health of the blood system. If there is a low level of hematocrit in the body, it shows that there is less proportion of red blood cells in the blood. It is an important parameter to know about the health of athletes. The level of hematocrit in athletes must be more normal as compared to the hematocrit level of a layman. Recent studies have shown that the positive impact of high altitude training is that it increases the number of red blood cells in the body, which in turn improves the hematocrit level of the body(Park et al., 2022). The increased number of red blood cells in the body helps to increase the transport of oxygen in the body. Both types of respiration take place in the body of an athlete including aerobic and anaerobic respiration. Sometimes the need for muscles cannot be fulfilled by aerobic respiration so there is a need to perform anaerobic respiration in the body. It has been proved that by high altitude training, the body of athletes become accustomed to performing anaerobic respiration as well in case of the absence of oxygen in the body. It is one of the important implications of high-altitude training that it helps regulate the normal level of hematocrit in the body which ultimately helps in better performance and endurance of athletes' bodies. This is the reason that high altitude training has too much importance these days(Ramos-Campo et al., 2015; Sun et al., 2023).

3.3 Improved Functions of the Body Including Cardiovascular Function and Respiratory Functions

Recent studies have shown that high-altitude training impacts the body of an athlete in various ways(Bailey & Davies, 1997). If we talk about improvement in cardiovascular function by high altitude training, it has been proved that high altitude training helps in the proper functioning of cardiac muscles which in turn maintain heart rate thus increasing the endurance of the athlete's body. If we talk about respiratory function in the body, it has been seen that high-altitude training has a positive impact on the respiratory system as well. When an athlete's body becomes accustomed to performing respiration at a low level of oxygen as well, it shows that they have better health, which is one of the positive aspects related to the performance of athletes. If we talk about the skeletal system of the body, there is no doubt that muscles perform well when they undergo consistent training(Sitkowski et al., 2019). When muscles become accustomed to anaerobic respiration, the overall growth of skeletal muscle increases which helps enhance athlete's performance and endurance

during sports. Better health of skeletal muscles is mandatory for effective performance because muscle strength is related to power and endurance during high-impact sports.

3.4 Better Lactate Threshold in Athlete's Body

The factor of lactate threshold can be enumerated as the maximum intensity of exercise that a body can bear in a specific interval of time. It is a common observation that at the start of training, there is very little ability of the body to bear the hard intensity of exercise. But when these exercises are performed continuously, the body of the athlete becomes habitual which in turn enhances the endurance of the body of an athlete(Moges et al., 2024). All types of training have an impact on the body to increase the lactate threshold level of the body, but it has been proved by scientific studies that high altitude training is more able to increase the lactate threshold level of an athlete's body(Płoszczyca et al., 2018; Rusko et al., 2004).

3.5 Descriptive Statistic

Table 1: Result of Descriptive Statistic

	AT	HP	EP
MEAN	1.399763	1.563721	1.400583
MEDIAN	1.332500	1.343500	1.342000
MAXIMUM	2.323000	2.766000	1.901000
MINIMUM	1.023000	1.021000	1.143000
STD. DEV.	0.288225	0.445511	0.175506
SKEWNESS	1.625192	1.378055	1.049208
KURTOSIS	5.895424	4.053645	3.922775
JARQUE-BERA	18.94847	8.706312	5.254866
PROBABILITY	0.000077	0.012866	0.072264
SUM	33.59430	37.52930	33.61400
SUM SQ. DEV.	1.910691	4.565049	0.708454
OBSERVATIONS	24	24	24

The result mentioned above in table 1 illustrates how descriptive statistical analysis demonstrates mean values, median rates, minimum and maximum values, as well as how each variable's independent and dependent standard deviation values are explained. Based on the results, the AT is the primary independent variable, with a mean value of 1.399. 1.33 is the median rate. According to the standard deviation rate of 0.288, 28% of data vary from the mean. The total probability of AT, which is 0.00077, indicates that there is a 100% significant difference between them. With a mean value of 1.563 and a standard deviation rate of 0.44, the HP functions as a mediator variable and indicates that 44% of the data deviates from the mean. According to table-1 the likelihood score of 0.012 indicates that there is a 12% meaningful difference

between them. The outcome furthermore reveals a 1.3780 skewness rate. The square deviation rate added up is 4.5650. Based on the results, the EP is a dependent variable, with a mean value of 1.400. There is a 17% standard deviation rate. The likelihood value of 0.07 indicates that there is a 7% significant difference between them. The outcome shows that the total of square deviation rate is 70%. The fact that the aggregate value between them is positive—33.61400—illustrates.

3.6 Unit Root Test Analysis

Table 2: Result of Unit Root Test Analysis

NULL HYPOTHESIS: AT HAS A UNIT ROOT			
EXOGENOUS: CONSTANT			
LEG LENGTH: 0 (AUTOMATIC - BASED ON SIC, MAXLAG=5)			
		T-STATISTIC	**PROB.***
AUGMENTED DICKEY-FULLER TEST STATISTIC	-5.214957		0.0003
TEST CRITICAL VALUES:	1% Level	-3.752946	
	5% Level	-2.998064	
	10% Level	-2.638752	
*Mackinnon (1996) One-Sided P-Values.			

The result above in table 2 shows how the unit root test analysis result describes the values of the t statistic as well as the probability of each element. The t statistic value of -5.2149, and the probability value of 0.0003 indicates that there is a 100% significant degree of agreement between them, according to the enhanced dickey-fuller test statistic. The t statistic values for the 1%, 5%, and 10% levels are -3.7529, -2.9980, and -2.6387, respectively.

Table 3: Result of Augmented Dickey-Fuller Test Equation

AUGMENTED DICKEY-FULLER TEST EQUATION				
VARIABLE	**COEFFICIENT**	**STD. ERROR**	**T-STATISTIC**	**PROB.**
AT (-1)	-1.126732	0.216058	-5.214957	0.0000
C	1.583568	0.307373	5.151948	0.0000
R-SQUARED	0.564277	Mean dependent var		0.013491
ADJUSTED R-SQUARED	0.543528	S.D. dependent var		0.439508
S.E. OF REGRESSION	0.296943	Akaike info criterion		0.492390
SUM SQUARED RESID	1.851682	Schwarz criterion		0.591129
LOG-LIKELIHOOD	-3.662487	Hannan-Quinn criter.		0.517223
F-STATISTIC	27.19577	Durbin-Watson stat		2.012547
PROB(F-STATISTIC)	0.000036			

The above results of table 3 show the coefficient values, standard error values, t statistic values, and probability values for each variable in the dickey-

fuller test equation. Table-3 describe the t statistic value is -5.2149 and the coefficient value is -1.1267. The probability value of 0.000 indicates a considerable yet negative relationship between them. A R square of 0.5642 indicates a 56% model fit for the analysis. There is a 54% corrected R-square value. The probability value of 0.000 and the F statistic rate of 27.195 indicate a 100% significant level of relationship between them.

3.7 Histogram and State

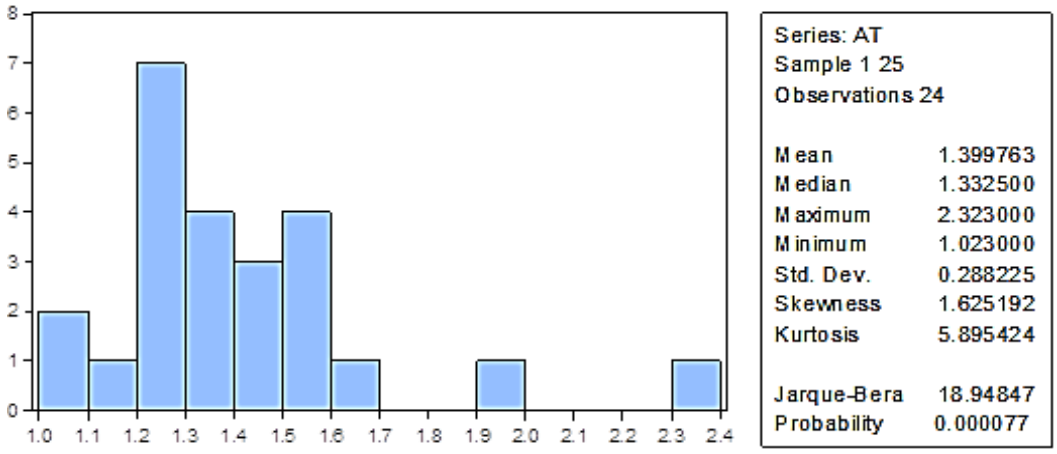

Figure 1: Histogram and State

The state analysis result and histogram the following graph in figure 1 indicate that the mean value is 1.399. 1.3325 is the median rate. According to the standard deviation rate of 0.288, 28% of data vary from the mean. The 100% significant level between them is shown by the probability level of 0.000. The state analysis and histogram between them are displayed by the blue bar line.

3.8 Linear Regression Analysis

Table 4: Result of Dependent Variable: EP

DEPENDENT VARIABLE: EP				
VARIABLE	**COEFFICIENT**	**STD. ERROR**	**T-STATISTIC**	**PROB.**
C	1.738746	0.203331	8.551328	0.0000
AT	-0.079235	0.122228	-0.648258	0.5238
HP	-0.145328	0.079076	-1.837833	0.0803
R-SQUARED	0.162996	Mean dependent var		1.400583
ADJUSTED R-SQUARED	0.083282	S.D. dependent var		0.175506
S.E. OF REGRESSION	0.168039	Akaike info criterion		-0.612774
SUM SQUARED RESID	0.592979	Schwarz criterion		-0.465517
LOG-LIKELIHOOD	10.35329	Hannan-Quinn criter.		-0.573707
F-STATISTIC	2.044746	Durbin-Watson stat		2.277114
PROB(F-STATISTIC)	0.154397			

The results above show that independent and dependent variables were

included in the linear regression analysis between them. The results also explain the coefficient analysis, t statistical analysis, and probability value between them. The coefficient values for the AT and HP are -0.0792 and -0.145. table-4 describes the t statistic value of -0.648 indicates a negative value between them, as does -1.8378. The probability value is 0.52, and the degree of significance between them is 0.080. The total R square value is 0.16, indicating a 16% significant difference in rating between them. The probability value of 0.15 indicates that there is a 15% significant difference between them.

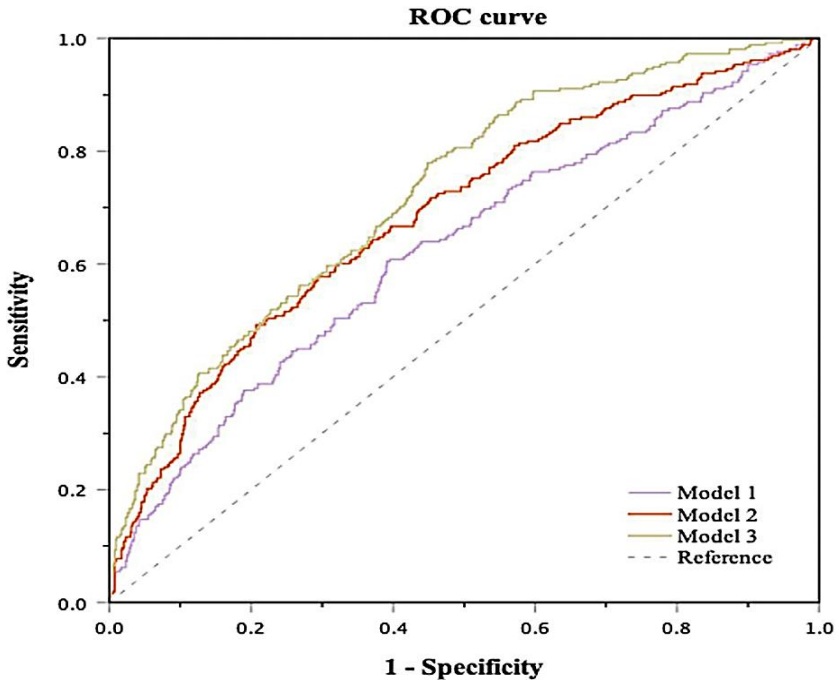

Figure 2: ROC curve

The above graph shown in figure 2 represents that hematological parameters graph shows that vertical side present sensitivity and horizontal side represent the specificity its range level is 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 respectively. The above line represents the hematological parameters effects on performance.

4. Discussion and Conclusion

The ramifications of high-altitude training discussed above demonstrate why it must be an essential part of any program designed to improve an athlete's performance and endurance. In both genders, there were important differences in the hematological parameters between AG and AAA. When an athlete practices and lives at a different elevation, this research provides coaches and sports physicians with essential information to monitor that player's hematological profile and general health. Although it is yet unknown how well altitude exercise could alter hematological variables, it has potential benefits. It is necessary to do more research and have a more thorough

understanding of the variables impacting the reaction to altitude and the variables influencing accurate measurement and result interpretation. The effectiveness of altitude or hypoxia training, which has been recommended for almost 50 years as a way to enhance sea-level sports performance, is still up for debate. Still, a lot of research support the ergogenic advantages of exercising at altitude for athletes. It has been found that the effects of altitude training on haematological variables are not always consistent. These discrepancies might be caused by differences in the amount of time people were hypoxic, the intensity of the hypoxic stimulus, the kind of training model used, the amount and quality of activity they did throughout the trial, and their level of physical fitness. It is equally important for researchers to employ methodological approaches and measuring procedures. Some endurance athletes engage in altitude training, which is working out for many weeks at a high altitude—ideally above 2,400 meters (8,000 feet) above sea level. However, because there aren't many suitable high-altitude areas, altitude training is often done at intermediate levels. The air is still around 20.9% oxygen at intermediate heights, but the partial pressure of oxygen is lower due to a decline in barometric pressure. Overall, the research revealed a significant and direct relationship between them. Depending on the procedures followed, the body may adapt to the relative lack of oxygen in one or more ways. For instance, it could alter how muscles metabolize oxygen or increase the production of haemoglobin and red blood cells. Advocates contend that these athletes have an advantage over competitors because their red blood cell content will remain higher for ten to fourteen days even when they go to competitions at lower altitudes. Some athletes decide to live year-round at high elevations and only descend to compete; nevertheless, their training may suffer due to reduced oxygen available for activity. To simulate altitude training, one can employ an altitude simulation tent, altitude simulation room, or mask-based hypoxicator system. These devices lower the partial pressure of oxygen while maintaining a constant oxygen content. Since hypoventilation exercise greatly lowers blood and muscle oxygenation, it can be compared to altitude training. Hypoventilation training is the practice of decreasing breathing frequency while exercising. Hypoxic training, in which athletes' practice in a simulator that replicates the circumstances of a high-altitude setting, is another application for artificial altitude. The musculoskeletal systems of athletes are not as taxed as they would be if they train harder and slower. An athlete recuperating from a musculoskeletal condition who is unable to attain the elevated stress levels during exercise that is typically required to deliver high-intensity cardiovascular training may find this useful. Exercise-induced hypoxia exposure is insufficient on its own to alter hematologic parameters. The concentrations of haemoglobin and hematocrit are usually unchanged.

REFERENCES

Bahenský, P., Bunc, V., Tlustý, P., & Grosicki, G. J. (2020). Effect of an eleven-

day altitude training program on aerobic and anaerobic performance in adolescent runners. *Medicina*, *56*(4), 184.

Bailey, D. M., & Davies, B. (1997). Physiological implications of altitude training for endurance performance at sea level: a review. *British Journal of Sports Medicine*, *31*(3), 183-190.

Banfi, G., Roi, G., Dolci, A., & Susta, D. (2004). Behaviour of haematological parameters in athletes performing marathons and ultramarathons in altitude ('skyrunners'). *Clinical & Laboratory Haematology*, *26*(6), 373-377.

Berglund, B. (1992). High-altitude training: aspects of haematological adaptation. *Sports Medicine*, *14*, 289-303.

Castro, H. O., Costa, G.C., Lage, G.M., Praça, G.M., Fernandez-Echeverría, C., Moreno, M.P., Greco, P.J. (2019). Visual Behaviour and Decision-Making in Attack Situations in Volleyball. *Revista Internacional de Medicina y Ciencias de la Actividad Física y del Deporte*, *19*(75), 565-578 https://doi.org/10.15366/rimcafd2019.75.012

Constantini, K., Wilhite, D. P., & Chapman, R. F. (2017). A clinician guide to altitude training for optimal endurance exercise performance at sea level. *High altitude medicine & biology*, *18*(2), 93-101.

Dragos, O., Alexe, D. I., Ursu, E. V., Alexe, C. I., Voinea, N. L., Haisan, P. L., Panaet, A. E., Albina, A. M., & Monea, D. (2022). Training in Hypoxia at Alternating High Altitudes Is a Factor Favoring the Increase in Sports Performance. Healthcare,

Fernández-Lázaro, D., Mielgo-Ayuso, J., Caballero García, A., Pascual Fernández, J., & Córodova Martínez, A. (2020). Artificial altitude training strategies: Is there a correlation between the haematological and physical performance parameters. *Arch Med Deporte*, *37*, 35-42.

Fernández-Lázaro, D., Mielgo-Ayuso, J., Santamaría, G., Gutiérrez-Abejón, E., Domínguez-Ortega, C., García-Lázaro, S. M., & Seco-Calvo, J. (2022). Adequacy of an altitude fitness program (living and training) plus intermittent exposure to hypoxia for improving hematological biomarkers and sports performance of elite athletes: A single-blind randomized clinical trial. *International journal of environmental research and public health*, *19*(15), 9095.

Gürses, V. V., & Akgül, M. S. (2018). The Effects of Low Altitude Training on Erythropoietin Response and Hematological Variables in Elite Female Fencers. *Universal Journal of Educational Research*, *6*(10), 2169-2174.

Hahn, A. G., & Gore, C. J. (2001). The effect of altitude on cycling performance: a challenge to traditional concepts. *Sports Medicine*, *31*, 533-557.

Haile, D. W., Durussel, J., Mekonen, W., Ongaro, N., Anjila, E., Mooses, M., Daskalaki, E., Mooses, K., McClure, J. D., & Sutehall, S. (2019). Effects of EPO on blood parameters and running performance in Kenyan athletes. *Medicine and science in sports and exercise*, *51*(2), 299-307.

Heinicke, K., Heinicke, I., Schmidt, W., & Wolfarth, B. (2005). A three-week

traditional altitude training increases hemoglobin mass and red cell volume in elite biathlon athletes. *International journal of sports medicine*, *26*(05), 350-355.

Mancera-Soto, E. M., Chamorro-Acosta, M. L., Ramos-Caballero, D. M., Torrella, J. R., & Cristancho-Mejía, E. (2022). Effect of hypobaric hypoxia on hematological parameters related to oxygen transport, blood volume and oxygen consumption in adolescent endurance-training athletes. *Journal of Exercise Science & Fitness*, *20*(4), 391-399.

Mancera-Soto, E. M., Ramos-Caballero, D. M., Rojas J, J. A., Duque, L., Chaves-Gomez, S., Cristancho-Mejía, E., & Schmidt, W. F.-J. (2022). Hemoglobin mass, blood volume and VO2max of trained and untrained children and adolescents living at different altitudes. *Frontiers in physiology*, *13*, 892247.

Martinez-Bello, V. E., Sanchis-Gomar, F., Nascimento, A. L., Pallardo, F. V., Ibanez-Sania, S., Olaso-Gonzalez, G., Calbet, J. A., Gomez-Cabrera, M. C., & Vina, J. (2011). Living at high altitude in combination with sea-level sprint training increases hematological parameters but does not improve performance in rats. *European journal of applied physiology*, *111*, 1147-1156.

Moges, T., Dhamodharan, M., Gebretensay, M., Kiflu, A., & Kentiba, E. (2024). Effects of Altitude training on Ethiopian endurance athletes recovery heart rate and hematological variables. *Pedagogy of Physical Culture and Sports*, *28*(3), 213-221.

Park, H.-Y., Jung, W.-S., Kim, S.-W., Kim, J., & Lim, K. (2022). Effects of interval training under hypoxia on hematological parameters, hemodynamic function, and endurance exercise performance in amateur female runners in Korea. *Frontiers in physiology*, *13*, 919008.

Płoszczyca, K., Langfort, J., & Czuba, M. (2018). The effects of altitude training on erythropoietic response and hematological variables in adult athletes: a narrative review. *Frontiers in physiology*, *9*, 322314.

Ramos-Campo, D. J., Martínez-Sánchez, F., Esteban-García, P., Rubio-Arias, J., Clemente-Suarez, V. J., & Jiménez-Díaz, J. F. (2015). The effects of intermittent hypoxia training on hematological and aerobic performance in triathletes. *Acta Physiologica Hungarica*, *102*(4), 409-418.

Rusko, H., Tikkanen, H., & Peltonen, J. (2004). Altitude and endurance training. *Journal of sports sciences*, *22*(10), 928-945.

Saunders, P. U., Pyne, D. B., & Gore, C. J. (2009). Endurance training at altitude. *High altitude medicine & biology*, *10*(2), 135-148.

Schmidt, W., Heinicke, K., Rojas, J., Gomez, J. M., Serrato, M., Mora, M., Wolfarth, B., Schmid, A., & Keul, J. (2002). Blood volume and hemoglobin mass in endurance athletes from moderate altitude. *Medicine & Science in Sports & Exercise*, *34*(12), 1934-1940.

Sitkowski, D., Szygula, Z., Surała, O., Orysiak, J., Zdanowicz, R., Pokrywka, A., Starczewski, M., & Malczewska-Lenczowska, J. (2019). Hematological

status and endurance performance predictors after low altitude training supported by normobaric hypoxia: a double-blind, placebo-controlled study. *Biology of Sport*, *36*(4), 341-349.

Strzała, M., Ostrowski, A., & Szyguła, Z. (2011). Altitude training and its influence on physical endurance in swimmers. *Journal of human kinetics*, *28*(2011), 91-105.

Sun, G., Xu, J., & Zuo, M. (2023). THE ROLE OF MULTI-LAYER SPIRAL CT BASED PERFUSION IMAGING IN LUNG CANCER RADIOTHERAPY ASSESSMENT IN ATHLETIC PATIENTS. *rimcafd*, *23*(89).

Törpel, A., Peter, B., & Schega, L. (2020). Effect of resistance training under normobaric hypoxia on physical performance, hematological parameters, and body composition in young and older people. *Frontiers in physiology*, *11*, 523636.

Wehrlin, J. P., Marti, B., & Hallén, J. (2016). Hemoglobin mass and aerobic performance at moderate altitude in elite athletes. *Hypoxia: Translation in Progress*, 357-374.

Yan, B., Ge, X., Yu, J., Hu, Y., & Girard, O. (2021). Hypoxic re-exposure retains hematological but not performance adaptations post-altitude training. *European journal of applied physiology*, *121*, 1049-1059.