EFFECT OF LOW-ALTITUDE AND NEAR SEA-LEVEL TRAINING ON CARDIO-PULMONARY FUNCTIONS AND ELECTROLYTE LEVEL OF MALE AMATEUR ENDURANCE RUNNERS OF BAUCHI, BAUCHI STATE, NIGERIA.

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DECLARATION

I declare that the work in this thesis titled "**Effect of Low-Altitude and Near Sea-Level Training on Cardio-pulmonary Functions and Electrolyte Level of Amateur Endurance Runners of Bauchi, Bauchi State, Nigeria"** has been carried out by me in the Department of Human Kinetics and Health Education, Faculty of Education, Ahmadu Bello University, Zaria. The information derived from the literature has been duly acknowledged in the text and in references. No part of this thesis was previously presented for another degree or diploma at this or any institution.

_____ _____

Bulus Yuyu MAIYANGA Date

CERTIFICATION

This thesis, titled "**Effect of Low Altitude Near Sea-Level Training on Cardio-pulmonary Functions and Electrolyte Level of Amateur Endurance Runners of Bauchi, Bauchi State, Nigeria"** by Bulus Yuyu MAIYANGA meets the regulations governing the award of Doctor of Philosophy Degree (Ph. D.) in Exercise and Sport Science, Ahmadu Bello University, Zaria, Nigeria, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my beloved late parents, Mr. and Mrs. Maiyanga Yuyu.

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ABBREVIATIONS

EPO: Erythropoietin

HCT: Haematocrit

HIF1: Hypoxia inducible factor-1

HR: Heart rate

HR_{max}: Maximal heart rate

IAAF: International Association of Athletics Federations

LSD: Least Square Difference

PCr: Phosphocreatine

PO_2: Partial Pressure of Oxygen

RBCs: Red Blood Cells

RF: Respiratory Frequency

VO_{2max}: Maximum Volume of Oxygen Consumption

Na^+: Sodium

K^+: Potassium

Kg: Kilogram

SEN: Speed endurance

LLTH: Live low train high

LHTL: Live high train low

LHTH: Live high train high

LLTL: Live low train low

IHT: Intermittent hypoxic training

IHE: Intermittent hypoxic exposure

OPERATIONAL DEFINITION OF TERMS

Low Altitude: As used in this study is an elevation of 1,414 m above sea level as found in Pankshin, Plateau State, Nigeria.

Near Sea Level: As used in this study is an elevation of 628 m above sea level as found in Bauchi town in Bauchi Sate, Nigeria.

Altitude Training: It is the practice by some endurance athletes who train for a maximum of 3 weeks at elevations of between 1414 m and 2400 m above sea level.

Amateur Endurance Runners: Refers to 3, 000 m, 5,000 m and 10,000 m male long-distance athletes of Bauchi State, Nigeria who have never participated in any international competitions but have participated in state and national competitions.

Cardio-pulmonary: As used in this study refers to VO2 max, haematocrit, heart rate, respiratory frequency and speed endurance of amateur endurance runners of Bauchi State, Nigeria

Electrolyte level: As used in this study refers to Sodium and Potassium ion levels of male amateur endurance runners of Bauchi town, who served as participants in this study

ABSTRACT

The study assessed the effect of low altitude and near sea level training on cardio-pulmonary and electrolyte level of male amateur endurance runners of Bauchi State, Nigeria. Pankshin and Bauchi, which are located at altitudes of 1414 m and 628 m above sea level respectively were used as low altitude and near sea level centres for this study. Repeated-measures experimental research design was used for the study. Training was conducted in two different environments (low-altitude and near sea-level) with seven assessments (base-line, immediately after the first, second and third week of training at low-altitude and near sea-level) on seven variables (haematocrit, pulse rate, respiratory frequency, VO_2max, potassium ion, sodium ion and speed endurance). Training was maintained between 60 - 85% of maximal heart rate of individual runner from Monday to Saturday for a duration of three (3) weeks on each location. The population for the study was twenty (20) male amateur endurance runners of Bauchi and a sample size of fifteen (15) male amateur endurance runners of Bauchi were drawn using purposive and simple random sampling techniques. All training sessions were conducted between 7:00am to 8:30am and 4:30 pm to 6:00 pm. The daily training programme included road walk (6 – 12) km, hill training and interval sprint training on a 400 m track. The participants' haematocrit, pulse rate, respiratory frequency VO_2max, potassium, sodium and speed endurance were assessed at base-line, immediately after the first, second and third week of stay at each Centre. The descriptive statistics of mean and standard deviation were used to describe the data on the physical characteristics of the participants. The inferential statistics of repeated-measures analysis of variance and simple linear regression were used to test the hypotheses. An alpha-level of 0.05 was used to retain or reject the null hypotheses. The analysis of the results revealed that training at both low-altitude and near sea-level had statistical significant effect on pulse rate ($p = 0.000$); haematocrit level ($p = 0.000$); VO_2max ($P = 0.000$) and speed endurance ($p = 0.000$) of amateur endurance runners of Bauchi State, Nigeria. Based on these findings, it was concluded that three weeks each of training at low altitude and near sea level reduced pulse rate, increase haematocrit counts, improved VO_2max and improved speed endurance of male amateur endurance runners of Bauchi State, Nigeria. Thus, exposure to low-altitude and near sea-level training were shown to have improved the performance indices of male endurance athletes. Therefore, the researcher recommended that low-altitude and near sea-level training should be adopted as part of endurance runners training circle for optimal performance.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

From the knowledge of environmental physiology, humans dwelling places have been categorized as either low or high landers. Basically, most human beings are dwelling in lowland areas, where oxygen content is generally normal (Moore & Regensteiner, 1983; Persson & Persson, 2017). However, there are people who are dwellers of high-altitude for years, as those living on the Andean Altiplano (Andeans), on the Tibetan Plateau (Tibetans) and the Semian Plateau (Ethiopians); these individuals live on altitudes ranging between 3000 m to 4500 m (Petousi & Robbins, 2014; Persson & Persson, 2017). Permanent human habitation is difficult beyond 5500 m due to the hostile environmental conditions, which adversely affect human health and sports performance (Prasad, 2017). Continue exposure to hypoxia have resulted in physiological adaptations that include increase in pulmonary ventilation and improvement in oxygen transport, delivery and metabolism. These adaptations have been reported to results in optimal physical and cognitive performances in endurance related activities of humans (Muza, Fulco & Cymerman, 2004; Bakdima, Gunen & Dargak, 2019).

The common reported atmospheric and environmental changes that altitude climbers experience as reported by Pinilla (2014) include high solar radiation, low temperature, low humidity, high wind, and rough terrains. The environmental conditions at altitude is reported to become challenging with increasing ascent; which requires better behavioural and physiologic adaptations to maintain bodily functions, particularly among endurance athletes coming from sea level environment (Gallagher & Hackett, 2004; Pinilla, 2014). Persson and Persson (2017) stressed that training for competition at altitude came to limelight as a consequence of Mexico City hosting the Summer Olympics Games in 1968

at an altitude of 2,240 m (7349 ft) above sea level. Endurance events during the 1968 Olympic Games suffered significant poor performances compared to performances in the events in which the same athletes had competed at sea level (Persson & Persson, 2017). Since then, exposing athletes to different altitude camps has gained popularity among coaches and environmental sport scientists globally. who often train for several weeks at altitude environment, mostly at low (800 m – 2,000 m) to moderate (2,000 m – 3,000 m) altitude above sea level (Rusko, Tikkanen & Peltonen, 2004).

Based on continuous studies on the benefits of altitude training, the International Association of Athletics Federation (IAAF, 1994) classified altitude heights for beneficial training as heights of low-altitude at between 800 m and 1,200 m, medium altitude at between 1,300 m and 2,500 m, and high-altitude of greater than or equal to 3,000 m. Based on these classifications, most altitude training camps have been established within 1,400 m to 2,850 m, in places like Crans Montana (1,500 m), Keystone (2,835 m), Addis Ababa (2,400 m), Nairobi (1,840 m) and Ifran (1,820 m) (IAAF,1994). At these altitudes, the atmospheric pressure and air density decrease, however, the mixture of inspiratory gases in the air is the same as at sea level. Faramoushi, Bolboli and Valizadeh (2012) opined that barometric and partial pressure of gases in the air reduces on ascent to altitude as from 800m above sea level. As a result of the reduced content of oxygen even at low-altitude makes it difficult for the cells to absorb the required oxygen for utilization in the body, which in turn affects endurance performance (Faramoushi *et al.*, 2012). This low tissue oxygen content at altitude causes immediate increase in respiration and heart rate (Faramoushi *et al.,* 2012).The body therefore needs to acclimatize to the relative lack of adequate oxygen for delivery of nutrients to exercising tissues, which in response, the body has to produce more red blood cells and haemoglobin or alter muscle metabolism to meet

up the oxygen demands of exercising muscles (Rusko, Tikkanen & Peltonen, 2004; Chapman & Sinex, 2015).

Fulco (1988): Mazzeo, (2008); Savard (2011) stressed that upon exposure to altitude the body ventilatory processes increased such as breaths per minute and the depth of each breath. This result to movement of air deep within the lungs to have a higher pressure of oxygen than that of sea level, thus, increases the oxygen pressure within the lungs, to allow for more oxygen diffusion into the blood for tissues utilization (Fulco, 1988; Mazzeo, 2008; Savard, 2011). Furthermore, the increase in ventilation causes carbon dioxide to be expelled, making the blood less acidic (Muza, Fulco & Cymerman, 2004).

Immediate ascend to low-altitude stimulates ventilation, the carotid and aortic body becomes more sensitive to reduced content of oxygen in arterial blood (PaO_2) and immediate reduction in partial pressure of carbon dioxide with increases in ventilatory drive (Faramoushi *et al.*, 2012; Gumersall, 2012; Wyatt, 2014). A reduction in PaO_2 pave way for reduced CO_2 and hydrogen ion (H^+) concentration in the blood. Any buildup of bicarbonate (HCO_3^-) is excreted through the kidneys gradually (Gumersall, 2012; Wyatt, 2014).

Physiologically, ascending at low-altitude (800 m – 2,000 m), leads to increase cardiac output to make up for reduced PaO_2 and reduced oxygen in the tissues, thereby increasing heart beats per minute while stroke volume remains low due to the reduction in plasma volume (McArdle, Katch & Katch, 2010; Naeije, 2010). These physiological processes do often persist for some days to allow for improvement in oxygen extraction in the tissues (McArdle *et al*., 2010; Naeije, 2010).

Endurance runners and coaches need to understand these physiological processes and the techniques to cope with these changes even at low altitude for enhanced

performance or else the performance will be impaired and this may lead to the manifestation of mountain sickness.

Research evidence has shown that with initial ascend to altitude of 2,000 m to 3,000 m haematocrit concentrations increase, but that the counts of the red blood cells remains the same. Haematocrit increase is as a result of reduced plasma volume (Wennecke, 2004; Brooks & Fahey, 2010). However, red blood cells production increases after a period of two to three weeks stay at altitude (Wennecke, 2004; Brooks & Fahey, 2010; Saunders, Garvican-Lewis, Schmidt, & Gore, 2013). Red cell mass is reported to significantly increase (Wennecke, 2004; Brooks & Fahey, 2010); allowing for increased oxygen delivery to exercising muscles, improving VO_2max and potentially improving speed endurance performances among endurance athletes.

Saunders, Garvican-Lewis, Schmidt, and Gore (2013); Barker (2018) stressed that potassium is the most available electrolyte inside the cells of the body and play an important role in many physiological functions, which include facilitation of carbohydrates processing for energy production, aid nerve impulse transmission, heart and skeletal muscle contraction.

Barker (2018) opined that maintenance of fluid levels outside the cells in the body is mainly the responsibility of sodium, which serves as an important factor in hydration. Lack of sodium in the body can lead to disruptions of physiological processes, particularly among endurance athletes who train for hours daily at altitude. Maintaining a balance of electrolytes at altitude is reported to enhance athletes' physiological adaptations and metabolism and thus foster recovery to training loads generally (Barker, 2018). Therefore, ensuring that these electrolytes are within normal range often go a long way in improving endurance performances at low-altitude and on return to near sea level.

Endurance performance capacity of athletes have been shown to improve through correct training modes, loads, periodization and acclimatization to altitude. When athletes are exposed to either low- moderate- or high-altitude training camps, the body acclimatizes to oxygen levels in the atmosphere, which in turn facilitates oxygen delivery to the exercising muscles. Physiologically, oxygen uptake and utilization are enhancers of endurance performance in athletes. However, endurance performances in events from 800m and above is negatively affected at low to moderate altitudes (Pinilla, 2014). This is due to low oxygen availability and the delivery to the tissues, which generally reduces the athletes' performance until when acclimatization processes have been achieved and adaptation to the low oxygen level of the environment is achieved (Muza, Fulco & Cymerman, 2004, Bakdima, Gunen & Dargak, 2019). Therefore, endurance runners can take advantage of low to moderate-altitude training periodization to enhance performance when the body adapts positively with training. These coping mechanisms most likely will help towards increasing endurance performances at sea level with correct periodization of training loads.

Bauchi town is 628 metres above sea level which fall within near sea level altitude classification (https://www.latlong.net>place>bauchi). Pankshin in Plateau State has an annual ambient temperature values between 20^{o}C and 25^{o}C with elevations of between1280 m to 2,650 m above sea level (Iloeje, 1981). These elevations in Pankshin fall within the low to moderate altitude classifications commonly recommended for endurance events training as practiced in Kenya, Ethiopia and other parts of the world (Hamlin, Marshall & Hellemans 2013) This varied position of Bauchi town in Bauchi State and Pankshin in Plateau State may serve as advantage for preparing distance runners to excel in both national and international competitions. It has been reported that endurance athlete and their coaches can take advantage of low-altitude camps and re-acclimatization

processes at near sea level to gain competitive edge at sea level competition (Muza, Fulco & Cymexman, 2004).

1.2 Statement of the Problem

Endurance runner's training at low-altitude environment in Europe, Asia and other developed and developing nations of the world including Nigeria always aimed at improving optimal performance of their athletes. Some of these programmes are clearly beneficial, to athletes such as increased haematocrit concentration, increased red blood cells production, increased VO_2max and increased oxygen delivery to exercising muscles which results to better endurance performance among athletes.

Unfortunately, in Nigeria including Bauchi State training of endurance runners at low altitude environment, the researcher observed that upon exposure to low-altitude, endurance athletes do face many physiological, respiratory and performance challenges resulting from acute variation of temperature and barometric pressures. Some of the immediate physiological challenges endurance athletes do face include insomnia, nausea, breathlessness, headache, dizziness, low arterial oxygen saturation, increased heart rate, increased pulmonary ventilation, decreased pulmonary oxygen diffusion and decreased blood volume Brooks & Fahey, 2010., McArdle, Katch, & Katch, 2010). All of these cardiopulmonary functions limit oxygen delivery to tissues, increased cardiac output, and increased incidences of acute mountain sickness (Brooks & Fahey, 2004; McArdle, Katch, & Katch, 2010), if ascent to low-altitude environment for endurance training is not properly organized and monitored, the situation becomes worrisome and unwholesome to endurance runners training at low altitude environment and therefore calls for careful investigation of the problem in each situation.

However, some studies have been conducted on the effects of low-altitude and near sea level training on cardiopulmonary and electrolyte level among endurance runners in

other countries of the World including Nigeria. Incidentally, none of such studies, to the best of the researcher's knowledge has been conducted in Bauchi State. Following this therefore, the need arose to study the effects of low-altitude and near sea level training on cardiopulmonary and electrolyte level among endurance runners, Bauchi State Nigeria. This is the crux of the study.

1.3 Research Questions

To guide the focus of the study, research questions were raised as follows:

1. Will low-altitude training and near-sea level training cause adaptation in pulse rate of Male amateur endurance runners of Bauchi State?
2. Will low-altitude training and near sea level training increase haematocrit level of Male amateur endurance runners of Bauchi State?
3. Will low-altitude training and near sea-level training improve respiratory frequency of Male amateur endurance runners of Bauchi State?
4. Will low-altitude training and near sea-level training improve VO_2max of Male amateur endurance runners of Bauchi State?
5. Will low-altitude training and near sea-level training cause adaptation in potassium ion level of Male amateur endurance runners of Bauchi State?
6. Will low-altitude training and near sea-level training cause adaptation in sodium ion level of Male amateur endurance runners of Bauchi State?
7. Would low-altitude training and near sea level training improve speed endurance of Male amateur endurance runners of Bauchi State?

1.4 Purpose of the Study

This study sought to find out the effects of low-altitude and near sea-level training on:

1. Pulse rate of Male amateur endurance runners of Bauchi State.

2. Haematocrit levels of Male amateur endurance runners of Bauchi State.
3. Respiratory frequency of Male amateur endurance runners of Bauchi State.
4. VO_2max of Male amateur endurance runners of Bauchi State.
5. Potassium ion level of Male amateur endurance runners of Bauchi State.
6. Sodium ion level of Male amateur endurance runners of Bauchi State.
7. Speed endurance of Male amateur endurance runners of Bauchi State.

1.5 Basic Assumptions

The following assumptions were raised for this study

1. Pulse rate rises on arrival at low-altitude environment among endurance athletes.
2. Haematocrit production is stimulated upon ascent to low-altitude camp among endurance athletes.
3. Respiratory frequency increases upon exposure to low-altitude environment among endurance athletes.
4. VO_2max is compromised on exposure to low-altitude but improves with steady adaptation among endurance athletes.
5. Potassium ion level is affected upon exposure to low-altitude environment but improves with acclimatization among endurance athletes.
6. Sodium ion level is compromised on arrival at low-altitude environment but improves with steady adaptation among endurance athletes.
7. Speed endurance is decrease immediately upon exposure to low-altitude camp but improves with steady adaptation among endurance athletes.

1.6 Hypotheses

The following hypotheses were formulated to guide the focus of this study:

Major Hypothesis

i. There are no significant effects of low-altitude and near sea-level training on cardio-pulmonary function and electrolytes level of male amateur endurance runners of Bauchi State, Nigeria.

Sub-Hypotheses

i. There are no significant effects of low-altitude and near sea-level training on pulse rate of male amateur endurance runners of Bauchi State. Nigeria.

ii. There are no significant effects of low-altitude and near sea-level training on haematocrit levels of male amateur endurance runners of Bauchi State, Nigeria

iii. There are no significant effects of low-altitude and near sea-level training on respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria

iv. There are no significant effects of low-altitude and near sea-level training on VO_2max of male amateur endurance runners of Bauchi State, Nigeria.

v. There are no significant effects of low-altitude and near sea-level training on potassium balance of male amateur endurance runners of Bauchi State, Nigeria

vi. There are no significant effects of low-altitude and near sea-level training on sodium balance of male amateur endurance runners of Bauchi State, Nigeria.

vii. There are no significant effects of low-altitude and near sea-level training on speed endurance of male amateur endurance runners of Bauchi State, Nigeria.

1.7 Significance of the Study

The findings of this research work on Pulse rate, haematocrit, respiratory frequency, VO_2max, potassium ion, sodium ion and speed endurance will be of great significance because of the following reasons:

The outcome of this study may provide information on strategies and training practices in sport science on the relationship between low-altitude training and cardiopulmonary functions of endurance runners. It will be of benefit to coaches, exercise

and sports scientists to identify areas of limitations with respect to low-altitude training and ways of overcoming such challenges for enhancing endurance performance among amateur athletes through engaging endurance athlete in low-altitude training.

The result of this study may be of value to coaches, exercise scientists and sports professionals to appreciate the importance of altitude training as a means of enhancing sport performance among endurance runners. Sport scientist, coaches and athletes can leverage on this information to design training protocols at low-altitude and practices at near sea level for endurance athletes to enhance their endurance events performance.

The results of the study will also contribute to the body of knowledge in sport science in identification of the effect of low-altitude and near sea-level training of amateur endurance runners for enhance sports performances in Bauchi State. Nigeria.

1.8 Delimitations of the study

The study was delimited to:

1. training at low-altitude (1414 m) above sea level in Pankshin, Plateau State, Nigeria.
2. training at near sea level (628 m) above sea level in Bauchi town, Bauchi State, Nigeria.
3. only male amateur endurance runners of Bauchi State who have participated in State and national competition within the age bracket of 20 to 30 years.
4. variables assessed were pulse rate, hematocrit, respiratory frequency, VO_2max, potassium, sodium and speed endurance of male amateur endurance runners of Bauchi State.
5. equal training duration of twenty-one (21) days each at low-altitude and near sea-level was adopted.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

Endurance athletes use altitude training to improve their performances and movement economy after return to sea level. An environmental condition with a reduced ambient oxygen has been reported to cause adaptive physiological changes among endurance athletes. The objectives of altitude training camps among these categories of athletes are to develop stronger aerobic base and running economy. The best time for planning altitude training camp exposure is during basic preparation phase immediately after the recovery phase of the yearly training cycle. IAAF (1994) recommended that altitude training camp should be planned for 21 to 28 days stay and a minimum of 12-14 days of training at sea level.

The chapter, reviews relevant and related literature to all the variables relating to altitude exposure of endurance athletes under the following sub-headings:

2.2 Altitude environments

2.3 Types of altitude training camps

2.4 Physiological responses and adaptations to low-altitude training exposure

2.4:1 Pulse rate response to altitude training

2.4:2 Haematocrit responses to altitude training

2.4:3 VO_2max responses to altitude training

2.4:4 Respiratory rate responses to altitude training

2.4.5 Potassium response to altitude training

2.4.6 Sodium response to altitude training

2.5 Effects and adaptation of altitude training at low-altitude

2.6 Altitude challenges on endurance events performances

2.7 Empirical reviews
2.8 Summary

2.2 Altitude Environment

An altitude is any elevation above sea level that produces physiological stress in humans. Most of these changes begin to manifest among sea level dwellers at low-altitude as from 800 m above sea level. In addition, the common environmental and atmospheric changes that altitude climbers experience include high solar radiation, low temperature, low humidity high wind (Pinilla, 2014). The environmental condition at altitude is hostile to sea level dwellers. It requires behavioural and physiologic adaptations to maintain body functions particularly among endurance athletes who undergo regular training of varied loads and intensities (Gallagher & Hackett, 2004; Pinilla, 2014).

Altitude environment has been categorized into low-, moderate- and high-altitude. High-altitude training camp is from 3,000 m; moderate altitude is between 2000 m to 3,000 m, while low altitude is seen as an altitude between 500 m to 2000 m above sea level (Adias, Escudero, Jackeline, Shailendra & Richard, 2012). According to Bartsch and Saltin (2008); Koechle, Cheng and Sporer (2014); Sinex and Chapman (2015) altitudes are classified as follows: sea level (0 -500 m), low-altitude (> 500 – 2000 m), moderate-altitude (> 2000 m – 3000 m), high-altitude (> 3000 – 5500 m), and extreme altitude (> 5500 m). \

Shah and Coplan (2016) stated that training at moderate-altitude enhances cardio-pulmonary performance, most especially endurance athletes that live and train at moderate-altitude to gain competitive advantage. Adaptation to lower partial pressure of oxygen (PO_2) at altitude enhances erythropoietin production that stimulates the production of red blood cells (RBC), thereby increasing oxygen delivery, potentially improving VO_2max and endurance performance (Saunders, Garvican-Lewis, Schmidt, & Gore, 2013). At low-

altitude, the body develop physiological adaptations that allow oxygen transport system to make up for hypoxia in turn regulate tissue oxygen level (Pinilla, 2014; Sinex & Chapman, 2015). Hypoxic environment improves delivery and utilization of oxygen, through adaptation of respiratory, cardiovascular and metabolic system that results to improved exercise economy, which are potentially important mechanisms contributing to performance improvement (Pinilla, 2014; Sinex & Chapman, 2015).

2.3 Types of Altitude Training for Enhancing Endurance Performance

Endurance performance have significant improvement over the last two decades because of relentless efforts of athletes and coaches to achieve higher competitive endurance performance. So many methods of training have been tested in order to find appropriate modalities of improving endurance performances (Porcari, Probst, Forrester, Doberstein, Foster, Cress & Schmidt, 2016).

Strzala, Ostrowski and Szygula (2011) stressed that athletes engage in altitude training to enhance their physical endurance and improve movement economy. A usual practice among endurance coaches and endurance athletes is altitude training because of the potential benefits during subsequent competition at or near-sea-level (Sinex & Chapman, 2015). studies have been carried out on moderate-altitude camp environment as means of improving endurance performance among athletes. Since 1968 Mexico City Olympics. presently, low-altitude training is used by many athletes and coaches and this method has shown promise in increasing endurance performance (Park, Hwang, Park, Lee, & Lim, 2016; Porcari et al., 2016)**.** The method has an inherent component of endurance training process, hypoxic stress at altitude facilitates reactions in the physiological make up of endurance athlete that lead to better adaptation and effective endurance performance at sea level (Isaev, Erlikh, Romanov & Bakhareva, 2016).

There are different training methods at altitude that may be beneficial to endurance athletes among which are: live low train-low (LLTL), live low train-high (LLTH), live high train-low (LHTL) and live high train- high (LHTH).

According to James and Wilkerson (2001) living and training at high-altitude (LHTH) by endurance athletes served as a means of constant and continuous stimulation of the athlete's body to hypoxic environment, and at the beginning there is drop in VO_2max (for every 1000 m above sea level there is 7% drop). At this level it becomes difficult for athletes to metabolize as much oxygen as they would at sea level. further stated that at high-altitude endurance performance for any given velocity must be performed at a higher relative intensity. Living and training at natural altitude environment of 1400 - 4000 m above sea level is commonly used to enhance physiologic adaptation such as improved red blood cells, haemoglobin concentration, haematocrit, maximal oxygen consumption, and exercise performance at sea-level (Park, Hwang, Park, Lee, & Lim, 2016; Sharma, Saunders, Garvican-Lewis, Clark, Stanley, Robertson & Thompson, 2017).

Levine and Stray-Gunderson (1991) stated that live high, train low (LHTL) is a method where athletes spend most of the time during the day and throughout the night at high-altitude of at least 2,000 m above sea level, and perform endurance activities sessions at near sea level (Millet, Faiss, Brocherie,& Girard, 2013). This is done with the aim of increasing the athlete's performance. Rusko, Tikkanen and Peltonen (2004) opined that athletes benefit from acclimatization by living at high-altitude and training at much lower altitude, the previous training intensity is maintained to prevent detrimental effects of chronic hypoxia. Rusko et al., 2004 suggested that the altitude should be between 1800 m and 2800 m and training at an altitude of less than 1300 m.

Levine (1991) in his study found that after four weeks of stay at an altitude of 2500 m and training at an altitude of 1300 m, there was 4.3% increase in VO_2max and 25%

faster in a 5-km time trail. In another study Levine (1991) using high-high altitude training (2800 m), High-Low (2800 m and 1250 m) and living and training low, at 150 m (low-low) for four weeks found increase in erythropoietin, RBC mass and VO_2 max of the altitude groups. The high low group reduced their time in the 5000 m trial compared with the pre-values.

Gore, Clark and Sounders (2007) opined that high-high and low method of training, which implies that athletes live at high-altitudes but train at high and low-altitudes encourages an athlete to do hard training one to three times per week at or near sea level. During the rest of the week, athletes do easily moderate exercises at high-altitude. The goal of LHTL method is to increase endurance at high-altitudes while incorporating the benefit of it at or near sea level training. Wehrlin, Zuest, Hallen and Marti (2006) acknowledged that simulated altitude programme relies on intermittent hypoxic training which prepare athletes for training and competing in high- and low-level areas. This form of training exposes athletes to high and low levels of oxygen during the training session. Athletes undergo mild hypoxia during each session to prepare the body for high-altitudes. Normally a series of signals are sent to the body representing hypoxia, this is more beneficial to the body than longer exposure to a hypoxic state. A non-training elevation of 2,100 m and training at 1,250 m or less was shown to be the optimal approach for altitude training. Good venues for live-high train-low include Mammoth lakes, California, Flagstaff, Arizona, and the Sierra Nevada near Granada Spain (Wehrlin, Zuest, Hallen & Marti, 2006).

Living low training high (LLTH) athletes live at sea-level and are exposed to relatively short intervals (<180 min) of intermittent hypoxic exposure (IHE) through the resting state and intermittent hypoxic training (IHT) during workout. LLTH reportedly enhances exercise performance by stimulating an increase in serum erythropoietin (EPO),

RBC count, skeletal muscle mitochondrial density, capillary-to-fibre ratio, fibre cross-sectional area via upregulation of hypoxia-inducible factor-1α (HIF-1α) (Vogt, Puntschart, Zuleger, Billerter, & Hoppeler, 2001; Powell, & Garcia, 2000; Schmidt, 2002). LLTH Particularly, plays an important role in increased athletic performance in altitude/hypoxic environment (Park et al., 2016).

Training performed in hypoxia causes amplified synthesis of the hypoxia inducible factor 1 (HIF1) is a dimeric protein complex that plays an integral role in the body's response to proline-hydroxylase-2 (Ziello, Jovin &Huang, 2007) influencing messenger RNA coding that determines the excretion of enzymes that are involved in muscle energy producing processes (Strzala, Ostrowski, & Szygula, 2011). Training sessions completed in hypoxia evoke a higher physiological adapaion than equivalent sessions completed in normoxia (Sharma *et al.*, 2017). East African dominance in long distance athletic performance has led researchers to believe that living and training at altitude have a role to play in enhancing sea level endurance performance. This is in line with Pinilla (2014), who stated that high-altitude inhabitant adaptation to hypoxic environment modify their respiratory, cardiovascular, and metabolic systems that resulted to improve oxygen delivery and oxygen utilization. Mclean, Vargas and Recibide (2013) reported that a pre-season training camp at 2100 m altitude produced 1.5% improvement in 2000 m running performance.

2.4 Physiological Adaptations and Responses to Altitude Training

A review of the adaptation and responses of the physiological parameters covered in this study are hereby discussed as outlined below:

2.4:1 Pulse Rate Response to Altitude Training

The demand for energy production rises quickly as work rate increases especially at high-altitude. To meet up for the increased energy demand, blood flow to the working

muscle tissue increases, this is accomplished primarily through an increase in pulse rate and stroke volume which increases cardiac output. Stroke volume increases in linear fashion up to 40-50% VO_2max. Where its levels off, pulse rate continues to increase as work rate increases in a positive linear fashion until heart rate maximum is achieved (Wildman & Miller, 2004).

Dikki (2001) reported that the pulse rate response to altitude training varies. In some athletes an initial elevation of resting heart rate occurs and persists; while in others, the pulse rate returns to its sea level values. Maximum achievable heart rate is unchanged, but it now occurs at slower work rate than at sea level. The blood volume pumped out with each beat of the heart (stroke volume) usually decreases (Dikki, 2001). As a result, maximum cardiac output never reaches the levels experienced by athletes at sea level. This helps to explain why athletes VO_2max at altitude is less than that at sea level. McArdle et al. (2010) opined that reduction in pulse rate implies an increase in stroke volume and cardiac output, which is believed to enhance an athlete's capacity for better performance. This reduction in pulse rate could be as a result of increased and continuous adaptation to training work load, improved mitochondrial density and re-acclimatization at near sea level (McArdle et al, 2010). Michele and Luigi (2011) also observed that immediately after exposure to altitude, cardiac output increases by an increase in heart rate. He further explained that not all studies show a statistically significant increase in red blood cell counts from altitude training. Increasing intensity of training due to increased heart and respiration rates improves training effects that last more than 15 days after return to sea-level.

Muza, Fulco and Cymerman (2004) revealed that, it is often for an individual's heart to beat and provide the oxygen and tissues with oxygenated blood and to return deoxygenated blood to the lungs. So, for the blood to be oxygenated again, it is partly

depended upon the density of oxygen present in the surrounding air. At high-altitude environment which is considered a location greater than 2000 m, the air possesses less oxygen. As a result, heart rate increases to deliver oxygen to cells in the body more efficiently, while at high-altitude the heart rate immediately speeds up when exercising; and while at rest at 2000 m, the heart rate increases to 10% over regular sea level value. At 4,500 m, the heart rate increases to 50% higher than its regular sea level rate. (Muza, Fulco & Cymerman 2004). It was further confirmed that when an individual travel to higher altitudes for a long period of time, the body acclimatizes and the resting heart rate decreases and returns to the same heart rate values than the person had at the altitude he traveled from. It takes about two weeks to complete the acclimatization process (McArdle et al, 2010). Therefore, many athletes arrive at a location a few days prior to their competition in order to perform at their regular abilities. While moving after a long period at high-altitude to a lower-altitude, there is usually a slight, decrease in heart rate as the heart normally becomes more efficient, but the acclimatization period is not nearly as extensive. Exposing the body to high-altitude causes it to acclimatize to the lower level of oxygen available in the atmosphere. Many of the changes that occur with acclimatization improve the delivery of oxygen to the muscles (McArdle et al, 2010). Therefore, more oxygen will lead to better performance particularly in the case of aerobic exercises. One of the adaptations occurring at medium altitude is a decrease in the heart rate at rest and at given loads, while the maximal pulse rate of the athlete remains unchanged. There is a decrease of peripheral resistance, but there is hardly any change of heart volume (Muza, Fulco & Cymerman 2004). Training at altitudes between 1,950 m and 2800 m, there was an increase in oxygen uptake of 12.5% at a pulse rate of 170 bpm. Even on the 13^{th} day after return to sea level, the value was 8.8% higher (IAAF, 1994).

2.4.2 Haematocrit Response to Altitude Training

The primary objective of several weeks of altitude training is to increase the total volume of red blood cells and oxygen delivery by increasing the oxygen-carrying capacity of the arterial blood (Rusko, Tikkanen & Peltonen, 2004). At low-altitude the lower partial pressure of oxygen induces erythropoietin production in the kidneys, which in turn stimulates the production of red blood cells in the bone marrow and yields down-stream increases in VO_2max and, thus, performance. Levine *et al.* (2005) opined that if the level and duration of moderate altitude training are sufficient, there is almost universal support for an increase in blood erythropoeitin and red blood cells. Clark, Quod, Clark and Crore, (2009) also supported the fact that during continuous exposure to classical altitude, serum EPO reaches a peak within 24 to 48 hours and, thereafter, declines to near base time levels. When an elite endurance athlete trains at low-altitude, the muscles capacity to receive and consume oxygen exceeds the ability of the cardiovascular system to transport oxygen (Wagner, 2000).

A consequence of acute exposure to altitude is a decrease in VO_2max and exercise performance. Highly trained athletes appear to be more susceptible to this decrease upon acute exposure to altitude because of the large reduction in arterial oxygen saturation (Clark, Bomdon, Schmidt & Aughcy, 2007). The mechanism for this greater decline in VO_2max at altitude in endurance athletes is largely due to their very high cardiac output and high pulmonary blood flow. With lower diffusion gradients for oxygen transfer at the pulmonary capillaries at high-altitude, the high pulmonary flow outstrips the diffusing capacity about 6 - 10% of sea level VO_2max and performance is lost for every 1,000 m of acute exposure to altitude (Levine, Strayhunderson & Mehta, 2008).

Levine and Stray-Gunderson (2014) suggested a training idea that involves living at higher altitudes in order to experience the physiological adaptations that occur such as

increased erythropoietin levels, increase count of red blood cells and higher VO_2max, while maintaining the same exercise intensity during training at sea level. However, due to the environmental differences at high-altitude, it may be necessary to decrease the intensity of the workouts. Chapman, Levine and Ventura (2010) remarked that an athlete's red blood cell count returns to normal levels within days of returning to sea level and that it is impossible to train at the same intensity that one could at sea level.

Altitude training can produce slow recovery due to the stress of hypoxia. Rusko (2008) states that exposure to extreme hypoxia at altitudes above 5000 m can lead to considerable deterioration of skeletal muscle tissue, five weeks at this altitude leads to a loss of muscle volume of the order of 10-15%. Rusko (2008) designed a high-altitude house for altitude training at sea level normal pressure with low concentration of oxygen about 15.3% equivalent to the oxygen available at high-altitude used for altitude training due to the reduced partial pressure of oxygen. Athletes live and sleep inside the house, but perform their training outside (at normal oxygen concentrations at 20.9%). The result of the study shows an improvement in erythropoietin and red blood cell counts.

Bartsch and Saltin (2008) opined that at high-altitudes there is decrease in oxygen hemoglobin saturation causing hypoxia-inducible factor-1(HIF1) to become stable and stimulate the production of erythropoietin secreted by the kidneys to stimulate red blood cell production from bone marrow to increase hemoglobin saturation and oxygen delivery. Some athletes demonstrate a strong red blood cell response to altitude while others see little or no gain in red cell mass with chronic exposure. It is uncertain how long this adaptation takes because various studies have found different conditions based on the amount of time spent at high-altitude. While erythropoietin occurs naturally in the body, it is also made synthetically to help treat patients suffering from kidney failure and to treat patients during chemotherapy over the past third years, erythropoietin has become frequently abused by

competitive athletes through blood doping and injections in order to gain advantage in endurance events. Abuse of erythropoietin, however, increases red blood cell counts beyond normal levels (polycythaemia) and increases the viscosity of blood possibly leading to hypertension and increasing the likelihood of a blood clot, heart attack or stroke. The natural Secretion of erythropoietin by the human kidneys can be increased by altitude training, but the body has limits on the amount of natural erythropoietin they will Secrete to, avoiding the harmful side effects of the illegal doping procedures (Heinicke *et al.,* 2005)

Rice *et al* (2005) in Risso, Geiser & Coste (2007) observed that after 1-2 days at altitude, blood erythropoietin level reached its peak value and then it progressively decreased to basic levels while the erythropoietin concentration decreased to basic values on 24 hours after the return to sea level. Pinilla (2013) observed in a study on exercise and training at altitude that when exercising at altitude, the body responds and adapt to two different stressors, hypoxia and exercise; the magnitude of the response to these stressors influence exercise capacity and performance and this response is mediated by the altitude level and individual characteristics.

Adjustments and acclimatization to altitude involve the central nervous, endocrine, respiratory and cardiovascular systems, the blood oxygen carrying capacity and morphologic and functional adaptations in the skeletal muscle. The acclimatization process aims to obtain an optimal oxygen tension of the arterial blood and to organs. High-ltitude training or training in hypoxia has been used by endurance athletes motivated by the expected advancement in aerobic and sea level performance. Some of the mechanisms of altitude acclimatization include increase in erythropoiesis, red blood cell count, mass blood hemoglobin concentration and VO_2max at mitochondrial level, elevated muscle efficiency and buffering capacity, as well as improvements in the structural and biochemical

properties of skeletal muscles. At tissue level, hypoxia promotes rapid oxygen sensing and subsequent cellular functions (Levine & Stray-Gunderson, 2001).

Plasma volume decreases due to water loss, related to dry environment and hyperventilation and to fluid shift from the intravascular space into the interstitial and intracellular spaces (Pinilla, 2013). This loss of plasma volume and the increase in erythropoiesis and reticulocytes induced by hypoxia cause the augmentation of total hemoglobin and the RBC mass. As a result, the oxygen-carrying capacity of the blood increases, as well as the oxygen content of arterial blood being higher than at sea level. A significant increase in the red blood cell mass may occur after three weeks at a minimum altitude of 2,100 m becoming more pronounced as altitude increases the main objective of altitude training is to stimulate these responses, and thus increase VO_2 max for performance improvement capacity both at altitude and sea level. The total haemoglobin (Hb mass) is strongly related to endurance performance at sea level. Studies demonstrated that elite athletes have approximately 35% higher Hb mass than the normal population. This is elevated further by 14% in athlete's native to altitudes of 2,600 m. Some studies have reported a significant increase in total hemoglobin mass and or red blood cell mass by 6-9% after 3-4 weeks of living and training at an altitude of greater (>) 2000 m. Nevertheless, this increase is not enough to close the gap in total HB mass between elite athletes native and altitude. On the other hand, studies have not shown changes in total Hb mass, however these results may be related to illness during the study or training at an altitude less than 2000 m, which is considered a critical minimal altitude for a significant increase in erythropoiesis (Mclean, Vergas & Recibido, 2013)

Nancy (2008) also reported that after 48 hrs at altitude the bone marrow increases its iron uptake to form haemoglobin. Evaluation of iron levels and supplementation prior and during the stay at altitude is necessary to secure the proper activity of the bone marrow.

Inhibition of complete haematological adaptation to training at altitude has been connected to lack of iron and may account for the studies that have failed to show increase in haemoglobin concentration. Lemos, Laura. and Sarah, (2013) also reported that haemoglobin molecules begin to increase even at altitudes as low as 500 m above sea level.

2.4.3 Cardio-respiratory Response to Altitude Training

Numerous studies have investigated performance at altitude and adaptation to high-altitude with its counterparts at sea level. However, some immediate physiological responses to moderate and high-altitude include acute increase in heart rate during sub-maximal exercise that in turn increases cardiac output. This haemodynamic response compensates for the reduced oxygen content of the blood to ensure that adequate amounts of oxygen are transported to the tissues, including exercising muscles (Mazzeo, 2008). Savard (2011) supported this by stating that, on arrival at an elevation of 2,300 m and above, initiation of rapid physiological adjustments occurs to compensate for the thinner air and accompanying reduction in alveolar partial pressure of oxygen (PO_2). These physiological adjustment or responses are noticed in the increase in the respiratory drive to produce hyperventilation and increase in blood flow during rest and sub-maximal exercise. They further confirmed that resting systemic blood pressure increases in the early stages of altitude adaptation. In addition, sub-maximal exercise heart rate and cardiac output rise as much as 50% above sea level values while the heart's stroke volume remains unchanged. The increased sub-maximal exercise blood flow at altitude largely compensates for arterial desaturation, for example, a 10% increase in cardiac output during rest or moderate exercise off-sets a 10% reduction in arterial oxygen saturation, at least in terms of total oxygen transported through the body. Wilmore and Costill (2004) observed the following physiological responses of athletes exercising at high- and low-pressure environments:

a. As the partial pressure of oxygen (PO_2) decreases at altitude more air must be taken in, thus an increase in pulmonary ventilation is noticed to provide for adequate tissue oxygenation.

b. Pulmonary oxygen diffusion across the alveolar capillary membrane is dependent upon alveolar partial pressure of oxygen.

c. Muscle oxygen gas exchange: The pressure gradient between blood and muscle oxygen concentration is 74 mm Hg at sea level. At 2,400 m altitude the arterial partial pressure of oxygen is about 60 mm Hg, while tissue partial pressure of oxygen remains at 20 mm Hg a gradient of only 40 mm Hg or a decrease of nearly 50%.

d. Blood volume decrease soon after altitude exposure and level off after a few weeks.

e. Cardiac output increases at altitude to compensate for the reduced partial pressure of oxygen and decreased oxygen delivery to tissues

f. Metabolic adaptation, oxidative pathways are limited at altitude, there is a shift towards anaerobic energy sources

g. Maximal oxygen uptake/consumption This occurs at an altitude of about 1,400 m to 1,600 m and above. A decline in VO_2 max is related to a decline in the barometric pressure and the partial pressure of oxygen. VO_2max decreases by 11% for each 1,000m above the 1,600m level. This is also supported by Brook and Fahey (2010) who opined that on exposure to altitude, erythropoietin normally stimulates red blood cell production and eventually leads to higher haemoglobin and haematocrit in addition to a stimulated ventilation situation caused by the hypoxia of altitude. This causes carbon-dioxide removal and respiratory alkalosis, bicarbonate capacity, muscle and oxygen uptake at altitude. The decreased oxygen uptake could be improved little with prolonged exposure.

Hallagan and Pigman (1998) concluded that with acclimatization there is a reduction in resting and sub maximal heart rate indicating a return to normal homeostasis within the system. Cardiac contractility does not seem to be affected, yet stroke volume will diminish because of reduced cardiac filling pressure. The rate pressure product (that is the heart rate x systolic blood pressure), which is an indirect measure of myocardial oxygen consumption, has been shown to increase to nearly 100% of that shown at sea level with acclimatization. Calbet, Bonshal, Radegram & Saltine (2003) reported that an increase in altitude leads to a proportional fall in the barometric pressure and to a decrease in the pressure of the atmospheric oxygen. This produces hypobaric hypoxia that affects in different degrees of all body organs, systems and function. At high-altitude, the body must develop some adaptations and changes that allows the oxygen transport system to compensate for the hypoxia to maintain an adequate tissue oxygen level to support metabolism

Terrados (1992) suggests that a measurable decrease in maximum aerobic power among elite athletes is detectable even at 900 m altitude. This supports experiences of sea level middle- and long-distance runners who notice performance impairment when they perform at altitude as low as 700 m to 800 m. Beneficial physiological adaptations have been observed from runners' experiences at altitude. Training at altitude of over 1000 m provides an additional hypoxic stress similar to the changes seen with hard training at sea level. Several physiological adaptations mark the body's adjustment to altitude, more enzymes are produced by working muscles for oxidative metabolism. These are found particularly in the skeletal muscle mitochondria, which increase in size and numbers. There is also a greater utilization of fatty acids in the working skeletal muscles as primary fuel rather than glycogen. As a result, blood lactic acid is reduced during sub maximal work (Dikki, 2001). Allan, Hahn and Gore (2001) reported that the mechanism of enhancement

of endurance performance is probably an increase in the capacity to transport oxygen to the muscles which altitude training is capable to stimulating.

2.4:4 Respiratory Rate Response to Altitude Training

After each inhalation at altitude, oxygen in the alveoli passes to the blood to be transported to the tissues. This gas exchange between the alveoli and blood takes place due to a pressure difference called pressure gradient. The pressure of oxygen exerts in the alveoli is greater than the pressure of oxygen in the blood surrounding the lungs. This drives oxygen from the lungs into the blood and carbon-dioxide from interstitial tissues into the lungs. This shows that any reduction in the pressure of oxygen entering the lungs will reduce the pressure gradient; the result therefore is that less oxygen is being driven from the lungs into the blood (Wilmore & Costil, 2004).

It has also been reported that one of the physiological changes athletes experience on arrival to altitude is breathlessness, with increased pulmonary ventilation and heart rate. This increase in pulmonary ventilation is to reduce the amount of alveolar and blood carbon dioxide, which often leads to respiratory alkalosis. The kidneys often compensate this by excreting more bicarbonate ion, thereby decreasing the blood's buffering capacity and reducing the alkalosis (IAAF, 1994; Roberts, 1997).

At altitude pulmonary oxygen diffusion across the alveolar capillary membrane also dependent upon alveolar partial pressure of oxygen. This decreases as altitude increases, leading to a decrease in oxyhaemoglobin saturation. At sea level haemoglobin is 98% saturated but this falls to 92% at an altitude of about 2,400 m above sea level. Similarly, at an altitude of about 2,400 m the pressure gradient of arterial partial pressure of oxygen is about 60mm Hg, while tissue partial pressure of oxygen remains 40mm Hg. Thus, the pressure gradient decreases from 60 mm Hg at sea level to only 20mm Hg at higher altitudes. This is an almost 50% reduction in the diffusion gradient because the diffusion

gradient is responsible for driving the oxygen from the blood into the tissues. This change in arterial PO_2 at altitude is an even greater consideration than the small 6-8% reduction in haemoglobin saturation that occurs (Wilmore & Costil, 2004).

Wilmore & Costil (2004) also reported that pulmonary ventilation increases at higher altitude, both at rest and during exercise. This is because the number of oxygen molecules in a given volume of air is less at higher altitudes; therefore, more air must be inspired to supply as much oxygen as during normal breathing at sea level. Thus, the increase in ventilation is necessitated in order to bring in a larger volume of air to meet the altitude challenge. This situation is called hyperventilation at sea level. Molinero (2013) reported that a normal respiratory rate, which is also known as breathing frequency, respiratory rate or pulmonary ventilation rate (inhalation-exhalation cycle) stated that a typical respiratory rate range for a healthy adult is 12-20 breaths per minute. This shows that changes may occur with exercises of different modes and intensity.

2.4:5 Sodium Response to Altitude Training

Sodium is the most abundant cation in the body; it plays three main functions: fluid balance, osmotic regulation, and maintenance of membrane potential (Schmidt 2010) Sodium is extremely important for the regulation of fluid levels outside the cells in the body. It is an essential factor in hydration, as it “holds” water in the cells. While sodium is highly important as an electrolyte, it is found at excessively high levels in many foods and drinks (Barker, 2018).

Electrolytes are positively or negatively charged ions that conduct electrical activity to perform various functions within the body. Electrolytes must be present in proper concentrations to maintain fluid balance, muscle contraction and neural activity (Lewis, 2015). Electrolytes are electrically charged minerals in the body. Electrolytes are vital to health and act as chemical messengers in the body carrying electrical impulses from the

nerves to control all tissue function and movement. Changes in fluid status at altitude can cause an alteration in the concentration of hormones involved in maintaining a normal fluid and electrolyte (e.g., sodium. potassium) balance in the body. An imbalance of any of the electrolytes can lead to serious disruptions in physiologic function thereby affecting performance (Fulco,1988; Barker, 2018). Alteration in the concentration of hormones involved in maintaining a normal fluid and electrolyte balance in the body at altitude will negatively affect sport performance. Furthermore, an imbalance of sodium at altitude can lead to serious disruptions in physiologic function thereby affecting performance (Fulco,1988; Barker, 2018).

2.4:6 Potassium Response to Altitude Training

Potassium is the primary intracellular cation in the body; it plays essential roles in cellular metabolism and maintains membrane potential as well as promotes neuromuscular and cardiac function (Rhoda, Porter, & Quinitini, 2011; Schmidt, 2010) Potassium is integral to maintaining the body's fluid balance with sodium. it is one of the main electrolytes consistently lost in sweat. Potassium is the most abundant electrolyte found inside the cells of the body and is essential for many physiologic processes, including nerve impulse transmission, heart and skeletal muscle contraction, and processing of carbohydrates (energy production (Barker, 2018).

Changes in fluid status at altitude can be caused by an alteration in the concentration of hormones involved in maintaining a normal fluid and electrolyte balance in the body. An imbalance of potassium at altitude can lead to serious disruptions in physiologic function thereby affecting performance (Fulco, 1988; Barker, 2018).

2.5 Physiological Adaptation of Altitude Training at Sea Level

The adaptations that are generally observable with medium altitude training include about 30 -40% increase in maximum oxygen uptake, increase in the number and size of

mitochondria in trained muscles, increase in the activity of aerobic enzymes, increased intramuscular glycogen store, increase in the number and surface area of capillaries and as a result there is a general increase in aerobic threshold (Hahn, 1993). He further stated that if training of the same quality and quantity as at sea level is conducted at medium altitude, there should be first of all an intensification of the cardiorespiratory and metabolic adaptations as earlier mentioned in a certain sense, altitude has the same effect as an increase of work intensity. However, there are also qualitative changes as compared to training at sea level. These changes include an increase in total haemoglobin concentration and haematocrit which leads to an increase in blood viscosity which in turn causes increased hearts efficiency with these physiological adaptations have been found to persist in athletes that have been so trained at altitude even after two weeks of such training.

Allan, Hahn and Gore (2001) reported that a well-documented physiological effects of altitude training includes; increased natural hormone erythropoietin production, a boost in total blood volume, an increase in VO_2max, cranked-up haematocrit levels for provision of greater percentage of cells carrying oxygen, elevated capillary volume, a higher volume of mitochondria and an increase in the lungs ability to exchange gases efficiently. Also living at high-altitude and training at low-altitude has been reported to provide performance improvements in speed and endurance. These changes remain significant for few weeks at sea level for athletes that undergoes training at altitude.

Dick (1992) reported that when an athlete successfully completes an altitude training and returns to sea level and has successful competitions, several factors in addition to simple training at altitude play a contributory role and their effect cannot be quantified separately from the altitude training stimulus. For example, greater attention may be devoted to creating an optimally effective training plan. There may be more free time ensuring adequate sleep and nutrition, because of being away from the pressures of job and

or training. The addition of a hilly terrain typically found at altitude could produce an additional stimulus.

Dikki (2001) remarked that it is pertinent to note that after temporarily dislocating the athlete from sea level to train at altitude, there is normally the need for a period of acclimatization at sea level if the benefits of altitude adaptations are to be maximized at sea level competitions. He, therefore, suggested that the following considerations are necessary for practical application of altitude training to show effects or adaptations.

a. Less time is needed for training at medium altitudes if the competition is scheduled for sea level.

b. In preparation for competition at medium and high-altitude, several training periods of between 20-35 days duration at altitude are needed to enable the athlete adapt effectively to altitude.

2.6 Altitude Challenges on Sport Performance

At high-altitude, the air is less dense and blood absorbs less oxygen than at sea level, the muscles receive less oxygen leading to decline in aerobic capacity. The reduced oxygen level (hypoxia) is a challenge to the human body because oxygen is the primary source of energy for cell metabolism and, thus, a minor reduction in oxygen triggers a multitude of physiological responses within the body such as breathlessness, fatigue, increased heart rate, headache, dizziness, arterial oxygen saturation, increased pulmonary ventilation, decreased pulmonary oxygen diffusion, decreased blood volume, decreased VO_2max, diarrhea, lack of consciousness, nausea, appetite suppression, drowsiness, drop in training velocity and ameliorate mountain sickness. The higher altitude the more athletics' performance drops off (Miller, 2014). Exposure to this reduced oxygen level (altitude or hypoxia) is a challenge to the human body because oxygen is the primary source of energy for cell metabolism. Therefore, the body under this state of hypoxia will respond in time by

increasing the formed elements (haematocrit) in the blood stream to compensate for lower oxygen levels. This strives to produce the required amount of energy with less oxygen available, thereby improving the ability to utilize oxygen (Elaine & Katja, 2012).

As altitude increases, air temperature and pressure decrease and there is less oxygen available for aerobic activities. The increase in altitude (high-altitude) produces two contradictory effects on athlete performances, particularly those accustomed to living at low-altitude. For explosive events (up to 400 m, long jump, triple jump), the reduction in atmospheric pressure offers less resistance from atmosphere, making it easier to perform these activities at high-altitude than at sea level. No wonder records were broken and set at the 1968 Mexico City Olympic games in those activities, for example, men's 100 m record, set by Jim Hines of USA lasted for almost 15 years, to be replaced by another mark set by Calvin Smith at altitude in Colorado that lasted for another 4 years. Men 400 m record, set by Lee Evans of USA lasted for 20 years (Anonymous, 2013).

For endurance events (races of 5,000 m and above), the predominant effect is the reduction in oxygen, which generally reduces the athlete performance at high-altitude. These long duration activities place considerable demands on oxygen transportation, and the aerobic energy system are the most severely affected by the hypobaric conditions at altitude. Sports organizations acknowledge the effects of altitude on performance. Thus, the International Association of Athletics Federation (IAAF, 2014) ruled that performances achieved at an altitude greater than 1,000 m will be approved for record purposes.

2.7 Review of Empirical Studies

To conduct a study on effect of low-altitude and near sea level training on cardiopulmonary and electrolyte balance among endurance runners of Bauchi State Nigeria, some empirical studies that have been examine on the following variables: pulse rate, haematocrit, $V0_2max$, respiratory frequency, sodium, potassium and speed endurance.

Empirical studies were reviewed below to show the similarities and differences that exist compare to the present study in the aspect of: purpose of the study; research questions/hypotheses; research design; population of the study; sample and sampling technique; instrument of data collection and statistical tools used in the data analysis. Also, findings and recommendations of the various studies reviewed were stated.

Carr, Saunders, Vallance, Garvican-Lewis and Gore (2015) investigated Increased hypoxic dose after training at low-altitude with 9 hour per night at 3000 m normobaric hypoxia. Eighteen elite-level race walkers (12 males and 6 females) were trained for 21 consecutive days at low altitude (1380 m). Participants were assigned to one of two independent experimental groups or the control group, and the groups were matched for performance ability. A treadmill test was used to assess VO_{2max}, walking economy, velocity at VO_{2max} and lactate threshold. There was a significant, 4.0 ± 2.5% ($p = 0.02$) increase in VO_{2max} within the lowHH and a non-significant, 4.4 ± 5.6% improvement within the lowHH+NHnight group ($p = 0.08$). The change within the control group was 1.3 ± 3.7%. However, the change in VO_{2max} when compared between groups was non-significant ($p = 0.23$). Time to exhaustion increased by 8.9 ± 5.6%, ($p = 0.03$) within the low HH+NH night group, and by 7.7 ± 7.8% ($p = 0.01$) within the low HH group; an increase that was not statistically different between these two groups ($p = 0.55$). No significant differences for submaximal HR were observed between the three conditions ($p = 0.37$). The average submaximal VO_{2max} in the control group was significantly reduced compared with both low HH + NH night ($p = 0.01$) and low HH ($p = 0.01$), with no significant difference in the change scores between the two experimental groups ($p = 0.83$). The study demonstrates that the combination of low and moderate altitude exposure facilitates physiological and performance-related benefits.

Porcari, Probst, Forrester, Doberstein, Foster, Cress and Schmidt (2016) study on **"**Effect of wearing the elevation training mask on aerobic capacity, lung function, and hematological variables". Twenty-four moderately trained subjects completed 6 weeks of high-intensity cycle ergometer training. Subjects were randomized into a mask (n = 12) or control (n = 12) group. Pre and post-training tests included VO_{2max}, pulmonary function, maximal inspiration pressure, hemoglobin and hematocrit. No significant differences were found in pulmonary function or hematological variables between or within groups. There was a significant improvement in VO_2max and PPO in both the control (13.5% and 9.9%) and mask (16.5% and 13.6%) groups. There was no difference in the magnitude of improvement between groups. Only the mask group had significant improvements in ventilator threshold (VT) (13.9%), power output (PO) at VT (19.3%), respiratory compensation threshold (RCT) (10.2%), and PO at RCT (16.4%) from pre to post-testing. The trends for improvements in VT and PO at VT between groups were similar to improvements in RCT and PO at RCT, but did not reach statistical significance (VT p = 0.06, PO at VT p = 0.170). Wearing the ETM while participating in a 6-week high-intensity cycle ergometer training program does not appear to act as a simulator of altitude, but more like a respiratory muscle training device. Wearing the ETM may improve specific markers of endurance performance beyond the improvements seen with interval training alone

Bakdima, Gunen and Dargak (2019) Study "Effects of Moderate Altitude Training on Cardiorespiratory Endurance (VO2 max,) of Male Amateur Distance Runners in Plateau State, Nigeria". The study employed 1x4x1 factorial research design. Purposive sampling technique was used to select 15 out of 19 amateur distance runners who were dwellers of Shendam located at a low-altitude of 289 m on the basis of their performance in a VO_{2max} test Training was maintained between 60-80% of maximal heart rate of individual runners

on daily basis for a duration of 3 weeks. All training sessions were conducted between 7.00am – 8.30 am and 4.30pm -6.00 pm daily. The daily training programmes included road running (6-12km) hill training consisting of five repetitions of 200m and interval sprint training on a cinder track. The participants VO_{2max} were assessed at base-line, immediately after the first, second and third weeks of training. Descriptive statistics of mean, standard deviation and standard error of estimate were used to analyze the physical characteristics and performance scores of the participants. The inferential statistics of repeated measures analysis of variance was used to test the hypothesis at an alpha level of 0.05. The analysis of the result revealed that training at moderate altitude improved the VO_2max. (P = 0.000) of the Plateau state amateur distance runner. It was recommended that altitude training related programmes should be explored and encouraged by coaches and relevant agencies for performance enhancement among endurance athletes.

Lara, Gallo-Salazar, Puente, Areces, José Salinero and Del Coso (2016) study "Interindividual variability in sweat electrolyte concentration in marathoners". The study employed ecological experimental design. The study population was 157 experienced runners (141 men and 16 women) completed a marathon race (24.4 ± 3.6 °C and 27.7 ± 4.8 % of humidity). During the race, sweat samples were collected by using sweat patches placed on the runners' forearms. Sweat electrolyte concentration was measured by using photoelectric flame photometry. As a group, sweat Na+ concentration was 42.9 ± 18.7 mmol·L−1 (minimal-maximal value = 7.0–95.5 mmol·L−1), sweat Cl− concentration was 32.2 ± 15.6 mmol·L−1 (7.3–90.6 mmol·L−1) and sweat K+ concentration was 6.0 ± 0. 9 mmol·L−1 (3.1–8.0 mmol·L−1). Women presented lower sweat Na+ (33.9 ± 12.1 vs 44.0 ± 19.1 mmol·L−1; P = 0.04) and sweat Cl− concentrations (22.9 ± 10.5 vs 33.2 ± 15.8 mmol·L−1; P = 0.01) than men. A 20 % of individuals presented a sweat Na+ concentration higher than 60 mmol·L−1 while this threshold was not surpassed by any

female marathoner. Sweat electrolyte concentration did not correlate to sweat rate, age, body characteristics, experience or training. Although there was a significant correlation between sweat Na+ concentration and running pace ($r = 0.18$; $P = 0.03$), this association was weak to interpret that sweat Na+ concentration increased with running pace. The inter-individual variability in sweat electrolyte concentration was not explained by any individual characteristics except for individual running pace and sex. An important portion (20 %) of marathoners might need special sodium intake recommendations due to their high sweat salt losses.

2.8 Summary

Altitude is any elevation above sea level. The characteristics of this condition include the diminishing oxygen availability due to low barometric pressure. This reduction in partial pressure of oxygen on ascent to high-altitude leads to decreased tissue oxygenation. Exposure to these extreme environmental conditions has been recognized as a type of cardiovascular stress and it alters the body functions. The cardiovascular system undergoes substantial changes in altitude to compensate for the decreases in partial pressure of oxygen that accompanied increased altitude.

Altitude training is the practice by some endurance athletes who trained for several weeks at high attitude preferably over 2400 m above sea level, though more commonly at intermediate level altitudes of between 800 m - 2400 m above sea level are used due to the shortage of suitable high-altitude locations. At intermediate altitudes, the air still contains approximately 20.9% oxygen of the barometric pressure and, thus, the partial pressure of oxygen is reduced. Depending very much on the protocols used, the body may acclimatize to the relative lack of oxygen in one or more ways such as increasing the mass of red blood cells and haemoglobin or altering muscle metabolism. Proponents claim that when such

athletes travel to competitions at lower altitude, they will still have a higher concentration of red blood cells for 10-14 days or more, which gives them a competitive advantage. Available related literature has been reviewed in relevant areas of this work. They include: types of altitude training, heart rate response to altitude training, haematocrit response to altitude training, cardio-respiratory endurance and altitude training, and challenges of altitude training on sport performance. The work is a deliberate attempt towards exploring other relevant areas of research with regards to altitude study and sport performance.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This study assessed the effect of low-altitude training exposure and near sea level training on cardiopulmonary indices and electrolyte balance among amateur male endurance runners in Bauchi state, Nigeria. To achieve this purpose, the research design, population, sample and sampling techniques, instrumentation, research assistance, training protocols and test descriptions, sequence of tests, experimental control and statistical techniques were described in this chapter.

3.2 Research Design

A repeated-measures experimental research design was used for this study (1 x7 x 7). With this design, training was conducted in two different environments of low-altitude and near sea level. Repeated assessments at base-line, immediately after the first, second and third week of training at the two environments on the research variables are carried out as used by Bakdima et al. (2019). The duration for the research was three weeks each at low-altitude and near sea level without any break. The matrix of design is shown below:

Table 3.1: Matrix of 1 x 7 x 7 Design

Altitude Environments	**Days**	**Variables**
Low-altitude (1414m above sea level)	**Baseline 1st day**	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**
	7th	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**
	14th	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**
	21st	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**
Near sea-level (628m above sea level)	**28th**	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**
	35th	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**
	42th	**PR, HCT, RF, $V0_2$max, NA^+, K^+. Speed Endurance**

3.3 Population of the study

The population for this study consisted of all male amateur endurance runners of Bauchi State Sports Council. These were athletes who have been exposed to training and competitions at the State and National levels, but have not taken part in any international competition before and during the period of this study. There were twenty (20) male amateur endurance runners consisting of 3,000m and 5,000 m in Bauchi State Sports Council (BSSC), (BSSC Information Unit, 2019).

3.4 Sample and Sampling Technique

The sample size of this study consisted of fifteen (15) Amateur endurance athletes of Bauchi State Sports Council. The sample was drawn from male amateur endurance athletic group were selected due to the numbers, male amateur endurance runners between the ages of 20 and 30 years were purposively selected for this study, on the basis of ages, only eighteen (18) male endurance runners met the age inclusion criteria. To obtain a sample size of fifteen (15) athletes, the researcher wrote fifteen (15) 'YES' and three (3) 'NO' on pieces of paper, wrapped, placed in an opened container and properly mixed.

Using the simple random sampling technique, each athlete was instructed to pick a wrapped paper without replacement. All those who picked 'YES' were used for this study. Therefore, a sample size of fifteen (15) male amateur endurance runners were used for this research.

3.5 Instrumentation

The following research instruments were used for the study:

a) A standard 400 m track located at low-altitude of 1414 m above sea level in Pankshin
b) Network of hilly terrain, at low altitude of between 1280 m and 2000 m above sea level at Pankshin were used as training routes

c) A standard 400 m track located at near sea level of 628 m above sea level in Bauchi

d) Whistle

e) Three electronic stop watches

f) Sodium heparinised capillary tubes

g) Blood lancet

h) Plasticine (sealer)

i) Haematocrit centrifuge (model D-78532, 2007, Tuttlingen, Gemany)

j) Micro-haematocrit reader (S/N 08-04-145B, Hawksley and Sons, West Susex, UK.)

k) Spirometer

l) Digital Blood Pressure Monitor (Model BP 710 HEM-7113-Z) made by OMRON, China. Accuracy/ Calibration pressure ± 3 mm Hg or 2% of reading. Pulse ± 5% of reading

m) Labjeniks Electrolyte analyzer model Q-GTE 60

n) Recording sheets to record measurements, time, number of laps covered during assessments

o) Abubakar Tafawa Balewa Teaching Hospital Bauchi and General Hospital, Pankshin laboratories were used for the analyses of haematocrit concentration, potassium ion and sodium ion..

3.6.0 Research Assistants

The following research assistants were used for this study:

i. Two laboratory assistants who took blood samples and analyzed the samples

ii. Two nurses who assessed the pulse rate of the athletes

iii. The researcher assessed the respiratory indices of the participants

iv. Two coaches assisted with the training programme, assessment of VO_{2max} and speed endurance indices.

v. Generally, the researcher monitored all processes to ensure the right procedures were followed.

The research assistants were professionals in their various field. Therefore, they were briefed about the entire research processes.

3.6.1 Informed Consent Form

The selected participants for the study were adequately informed on the procedures, commitment required, the possible benefits of the training, the discomfort that may be experienced and necessary precautions during the period of the research. Informed consent form was given to each participant to read, ask questions and those who consented to participate in the study signed the consent column. A sample of the form is attached on appendix x. A pre – medical screening for malaria and other infections was carried out for all the participants prior moving the athletes to low-altitude camp from Bauchi town.

3.7 Training Protocols

All training sessions were carried out in the morning between 7:00 – 8: 30 am and in the evening between 4:30 – 6:00 pm for duration of three weeks each at low-altitude and at near sea level. Each training started with ten (10) minutes general warm up, which included: light jogging, dynamic and static stretching activities to prepare the athletes for the main activity. Warm down activity of 10 minutes was conducted consisting of jogging, static stretches and massages where necessary after each training session. The daily work outs are presented in table 3:2

Table3:2: Schedule of the Training Programme at Low-Altitude and Sea Level Centres

Week	Day	Morning (7:00 – 8:30 am)	Evening (4: 30 – 6: 00 pm)	Intensity (HR_{max})
1	Monday	8 km slow pace run	5(4 x 1200m) (Jog 100m to start and 400m between each set	60 - 65% HR_{max}
	Tuesday	Hill sprint training of 200m x 5 reps. at 35 sec. and jog back to start	6(3 x 400m) at 60 – 65 sec/lap Jog 200m and 400m between reps and set	65 - 70% HR_{max}
	Wednesday	12 km road work at moderate pace	6(4 x 200m) at 25 – 28sec. Jog 200m to start and jog 600m between each set	70 - 75% HR_{max}
	Thursday	4(30kg x 20 reps) of squats	40 minutes diagonal pace runs on a football pitch	60 - 65% HR_{max}
	Friday	4(3 x 600m (Jog 200m to start between reps and 600m after a set	8(10 x 150 m) Jog back 150m to start and 350m after a set	60 - 65% HR_{max}
	Saturday	Assessment and time trials on the variables		
2	Monday	15km moderate pace road work	5(3 x 500 m) Jog back 100m to start and 300m after a set	70 - 75% HR_{max}
	Tuesday	6(5 x 500m) at 70 -75sec. Jog back 100m to start and 350m after a set	4(6 x 300m) at 45 -50 sec. Jog 100m to start and 500m after a set	65 - 70% HR_{max}
	Wednesday	12 km steady pace road run	5(2 x 1000m) Jog 200m to start and 600m after a set	70 - 75% HR_{max}
	Thursday	20minutes continues pace run at 60% VO_2max 4(30kg x 3) 20 reps) of squats	3(8 x 200 m) at 30sec. Jog 200m to start and 600m after a set	70 - 75% HR_{max}
	Friday	12km road work at 70% HR_{max}	Dynamic and static stretching exercises	65 - 70% HR_{max}
	Saturday	Assessment and time trials on the variables		
3	Monday	8 km fast road work	8(3 x 500m Jog back 100m to start and 300m after a set	75 - 80% HR_{max}
	Tuesday	Hill training 120m x 5 (4sets) @ 20'' - 25"	8(5 x 200m at 26 – 30 sec. Jog 200m to start and 600m after a set	85 - 90% HR_{max}
	Wednesday	8(5 x 400 m) at 60 – 65 sec. Jog 200m between reps and 400m after a set	Sprint at interval each of 100m curve and straight runs for 30minutes continuously	75 - 80% HR_{max}
	Thursday	5(4 x 600m) at 75 – 80 sec. Jog 200m to start and 600m after a set	Dynamic and static stretching exercises. Sprints100m x 10) in 15 - 18sec. Jog back to start	65 - 75% HR_{max}
	Friday	6(8 x 300m) at 45 -50 sec. Jog 100m to start and 500m after a set	45 minutes continues pace runs on the grass	70 - 75% HR_{max}
	Saturday	Assessment and time trials on the variables		

Source: Adopted and modified from: Bakdima, Gunen and Dargak (2019).

Key: 5(4 x 1200m) (Jog 100m to start and 400m between each set means running 1200m of four repetitions with a recovery jogging of 100m. after 4 repetitions, the participants jogged 400m to start the next set

The first day training in the morning was 8 km slow pace run and during evening training the participants had four (4) repetitions of 1200m of four (4) sets. h 2 minutes rest between each set. All the day activities were carried out at an intensity of between 60 to 65% HR_{max}. The second day morning activity was hill training of 200 m x 5, rest period of

35 seconds, in the 400 m run on the track 2 times, four sets, all at intensity of 65 to 70% HR_{max}. Day three activities include 6 to 10 km road work in the morning, while evening activity was 200 m x 6 x 2 rest interval of 36 seconds at an intensity of 60 to 65% $HR_{max,}$ fourth day activities were weight training lifting of 30 kg weight 8 to 12 repetition 4 to 6 sets, in the evening 20 to 30 minutes diagonal run on a football pitch, all the activities at 70 to 70% $HR_{max.}$ Day five activities were 4 x 3 x 300 m jog to starting point for another repetition, in the evening 3 sets of 6 x 150 m run, the day activities were carried out at 60 to 65% $HR_{max.}$ day six activity were trials and assessment at an intensity of 70 to 75% $HR_{max.}$ while the seventh day was rest.

The second week training programme were: first day in the morning 8 km road walk at moderate pace and in the evening 3 sets of 3 x 450 m run with rest interval of 70 seconds at an intensity of 70 to 75% $HR_{max.}$ Second day 2 sets of 5 x 500 m of 5000 m pace and in the evening 4 sets of 3 x 300 m all at intensity of 65 to 70% $HR_{max.}$ Day three activities were in the morning 12 km steady run and in the evening was 2 sets of 2 x 1000 m of 5000 m pace, all at intensity of 70 to 75% $HR_{max.}$ Day four activities includes: morning 40 to 50 mins continues run at 60% $VO_{2MAX,}$ while evening was 3 sets of 4 x 200 m with rest interval of 30 seconds, all at intensity of 65 to 70% $HR_{max.}$ Day five 12 km long road work and in the evening stretching exercises and 150 m x 8 at an intensity of 65 to 70% $HR_{max.}$ Day six was trials and assessments while day seven rest.

Week three training programme included: First day 8 km fast road work and in the evening 3 sets of 3 x 500 m, at intensity of 75 to 80% $HR_{max.}$ Day two hill training 120 m x 5 and in the evening 2 sets of 4 x 200 m at 90% $VO_{2MAX,}$ with intensity of 65 to 70% $HR_{max.}$ Day three 3 sets of 5 x 400 m at 70 to 75% $VO_{2MAX,}$ and in the evening 100 m curve and straight run 10 x 4 times at intensity of 75 to 80% $HR_{max.}$ Day four, 2 sets of 6 x 150 m run and in the evening 30 to 50 minutes continues run at intensity of 75 to 80%

$HR_{max.}$ Day five 8 x 300 m and in the evening stretching exercises and 10 x 100 m at an intensity of 70 to 75% $HR_{max.}$ Day six trails and assessment at 80 to 85% $HR_{max.}$ The training programme was used for both low-altitude and near sea level. The training programme is presented in Table 3.2

3.8 Procedures for Data Collection

All parameters were assessed in the following sequence to avoid the influence of fatigue on the results.

Base-line measurements were carried out before the commencement of training and subsequently the variables were assessed immediately at the end of the first, second and third week of training at low-altitude and near sea level. The results of the third week of low-altitude assessment served as base-line for near sea level assessment.

All training and tests were conducted at the same venue and time, from 7:00 am to 8:30 am, on training days with the same instrument in order to maintained experimental control

3.8.1 Test Procedures and Descriptions

The procedure for the assessment of each variable are described below:

3.8.2 Measurement of Haematocrit

Haematocrit was determined by taking the blood samples of the athletes. The test was conducted by using the micro-haematocrit method with the following procedures as described by Selection of site (thumb print finger)

1. Swab the site
2. Punch the thumb using the blood lancet
3. Clean and press for the blood to be collected.
4. Collect the blood using the heparinised capillary tube up to ¾ of the volume.
5. Seal one end of the capillary tube (collection end) with plasticine
6. Centrifuge and spun using the haematocrit centrifuge for five minutes
7. Read the result of the packed cell volume (PCV), using the haematocrit reader and report in percentage.

The normal percentage range is usually as follows:

Adult male: 40 -54%

Adult female: 36 – 46%

Athletes: 37-55% for male and female

Anything below or above these values is considered abnormal (Dacie & Lewis, 1995, Cedaro, 2002; Cheesbrough, 2004). The measurements were taken at base-line, immediately at the end of the first, second and third week of training at both low-altitude and near sea level between 7:00 am and 8:30 am.

3.8.3 Measurement of Pulse Rate

The automated digital blood pressure monitor (Model BP 710 HEM-7113-Z) made by OMRON, China. Accuracy/ Calibration pressure ± 3 mm Hg or 2% of reading. Pulse ± 5% of reading was used to assess pulse rate of all the athletes. The following procedures was used

1. Measurement was taken in a quiet room
2. Athletes would remove tight clothing on the left arm
3. Each athlete was made to sit on a chair with the feet flat on the floor, resting the left arm on the table so that the cuff is at the same level with the heart
4. The cuff was applied to the left upper arm so that the arrow is entered on the inside of the arm and aligned with middle finger, the air tube runs down the inside of the arm.
5. The cuff was then wrapped firmly in place around the arm using the cloth fastening
6. The start/stop button was pressed and all the symbols appeared on the display window, the start cuff inflated automatically. As the cuff inflates, the monitor automatically determines ideal inflation level, while each participant remained

silent and did not move the arm until the entire measurement process was completed

7. Inflation stopped automatically and the measurement started as the cuff deflates, decreasing the pressure on the display window and the heart beat symbol flashes
8. When measurement was completed, the pressure completely deflates. Blood pressure (systolic/diastolic blood pressure) and pulse rate were displayed automatically.
9. The pulse rate was recorded for each participant (mm Hg) on the research recording sheet
10. The start/stop button was pressed to turn the monitor off in preparation for the next assessment.

The measurements were taken at base-line, immediately at the end of the first, second and third week of training at both low-altitude and near sea level between 7:00 am and 8:30 am.

3.8.4 Measurement of Respiratory Frequency

Procedures:

1. Each participant maintained an upright sitting position,
2. Each participant was instructed to take a deep breath with the spirometer worn or placed on the mouth with the clip piece tightly fixed.
3. The tester observed and noted the number of times the chest rises and the time spent between inspiration and expiration per minute.
4. The observed results were recorded accordingly in percentage of the inhalation and exhalation cycles

This measurement was taken for each participant at baseline and immediately at the end of the first, second and third week of training at low-altitude and near sea level.

between 7:00 am and 8:30 am.

3.8.5 Assessment of VO_{2max}

The 12-minute run-walk field test was used to estimate VO_{2max} in $m1.kg^{-1}.min^{-1}$ of the participants.

The procedure for VO_{2max} test were

1. The participants were grouped into three (3) of five participants and were made to warm up properly for 10 to 15 minutes prior to each group test.
2. Each participant was required to run or walk as fast as possible within the 12-minute period on a standard 400 m track
3. Each participant was timed using stop watch
4. The distance covered by each participant in 12 minutes was recorded in meters
5. $VO_{2\ max}$ was calculated using formula of Cooper (1968)

The formula for the calculation of $V0_{2max}$ as suggested by Cooper (1968) is (35.97 x miles) -11.29, or (22.351 x kilometer) – 11.288 where d_{12} is distance in miles covered in 12 minutes (ACSM (2002); Heyward (2010) and Quinn, 2019).

This measurement will be taken at baseline and immediately at the end of the first, second and third week of training between 7:00 am and 8:30 am, at low altitude and near sea level.

3.8.5 Measurement of Potassium and Sodium

Electrolytes balance were determined by laboratory test of blood samples from the participants. The tests were conducted using auto electrolyte analyzer with the following procedures.

1. Selection of site (thumb print finger)
2. Swab the site
3. Punch the thumb using the blood lancet

4. Clean and press for the blood to be collected.
5. 4 ml of blood was collected in a clean tube.
6. Seal the collection end with plasticine
7. After clot formation, samples were centrifuged at 3,000 RPM for 5 minutes
8. Separation of serum and collected in sample cups
9. Finally run in auto-analyzer for serum electrolyte determination.

Reference ranges (Normal values)

Serum

Sodium: 133 – 145 mmol/L

Potassium: 3.3 – 5.1 mmol/L

(C.D.C, 2016; Naz & Chugh, 2017).

3.8.6 Measurement of Speed endurance

Participants were subjected to 3,000 m race to determine their speed. Stop watches were used to determine the finishing time of the participants. This was conducted at baseline and immediately at the end of the first, second and third week of training at low-altitude and near sea level between 7:00 am and 8:30 am.

3.9 Procedure for Data Analyses

The data collected was analyzed and interpreted using the following statistical techniques:

i. Descriptive statistics of mean, standard deviation and standard error of means were used to describe the physical characteristics of the participants such as age, height and weight of the participants.

ii. The repeated-measures analysis of variance was used to determine any significant effect of training at low-altitude and near sea level. On the variables

iii. Post-hoc least square difference (LSD) test for multiple comparisons was used to establish which phase of training was responsible for the effect, if there was any

iv. Regression analysis was used to assess the sustainability of the training effect after the return to near sea level.

v. Decision to reject or retain the null hypotheses was made at an alpha level of 0.05.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Introduction

The purpose of this study was to assess the effect of low-altitude and near sea level training on cardiopulmonary functions and electrolyte levels of male amateur endurance runners of Bauchi State, Nigeria. To achieve this purpose, the data collected after low-altitude and near sea level training for duration of three weeks at each environment was analyzed, the results of which are presented and discussed in this chapter.

4.2 Results

The physical characteristics of the participants at base-line, immediately after the first, second and third week of training at low-altitude and near sea level are presented in Table 4.2.1

Table 4.2.1: Mean, Standard deviation and standard error of estimate of the age (years), weight (kg); and height (m) of the participants at baseline, immediately after the first, second and third week of training at low-altitudes and near sea level:

		Low-Altitude			Near sea level		
Duration	**Variable**	**Mean**	**SD**	**SE**	**Mean**	**SD**	**SE**
Baseline	Age (years)	24.00	2.449	.707	24.00	2.449	.707
	Weight (kg)	58.33	5.123	1.479	56.75	5.328	1.538
	Height (m)	1.67	.054	.016	1.67	.054	.016
1st week	Weight (kg.)	57.67	5.662	1.635	56.83	4.877	1.408
2nd week	Weight (kg.)	57.08	5.583	1.612	56.75	4.789	1.382
3rd week	Weight (kg.)	56.75	5.328	1.538	56.50	4.642	1.340

Table 4.2.1 shows the mean, standard deviation and standard error of mean of the age (years), weight (kg); and height (m) at baseline, immediately after the first, second and third week of training at low-altitude and near sea level of male amateur endurance runners used for this study. An observation of the baseline data of the participants showed that they were 24.00 ± 2.45 years old, with means weight and height of 58.33 ± 5.12 kg; 1.67 ± 0.054 m respectively. After the first, second and third week at low-altitude, the participants' body weight was 57.67 ± 5.66 kg, 57.08 ± 5.58 kg and 56.75 ± 5.32 kg

respectively. However, on returned to near sea level, the means body weight immediately after the 1st, 2nd and 3rd week were 56.83 ± 4.87 kg; 56.75 ± 4.78 kg and 56.50 ± 4.64 kg respectively. This showed a minimal reduction in their body weight as compared to low altitude values.

The graph of the body weight of the participants at baseline, immediately after the first, second, third, fourth, fifth and sixth week of training at low-altitude and near sea level are presented in figure 4.2.1

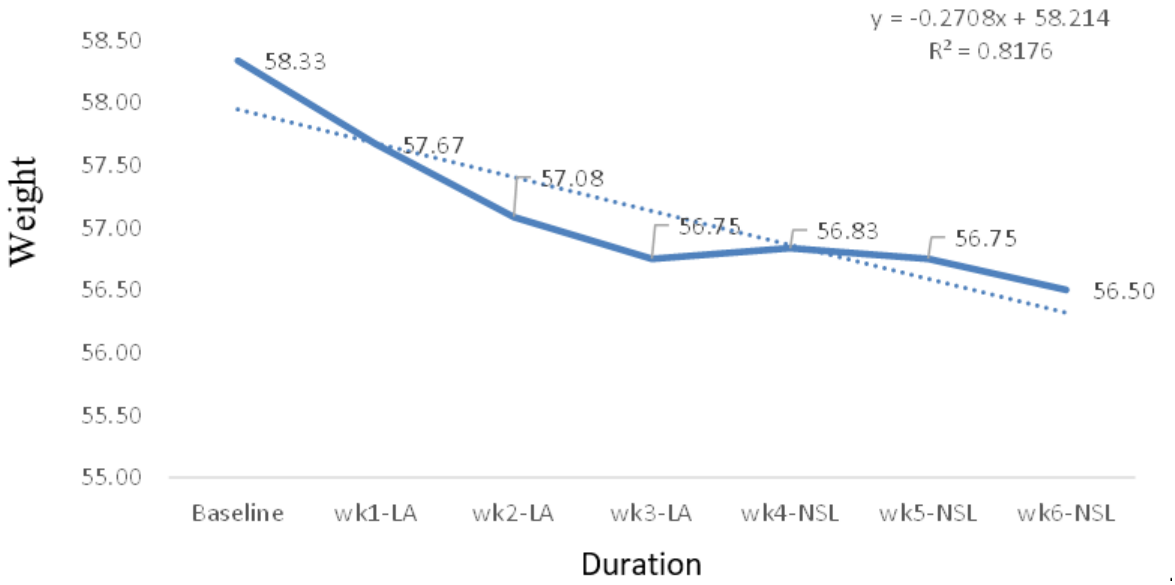


Figure 4.2.1: Graphic illustration of weight (kg) at low-altitude and near sea level

Key: ····· Regression line. ▬ Means per week, WK1-3 LA = Week 1 – 3 at low-altitude, WK4 – 6 NSL = Week 4 – 6 at near sea-level

Figure 4.2.1 shows means of weight (kg) of the participants at low-altitude and near sea level. The results indicated that there was a total reduction of 1.83kg in body weight of the participants which may be attributed to the training period.

Test of Hypotheses

In order to find out whether there was significant effect of training at low-altitude and near-sea level on the variables, the data collected were analyzed according to the hypotheses

Hypothesis I: **There are no significant effects of low-altitude and near sea level training on pulse rate of male amateur endurance runners of Bauchi State, Nigeria.**

To determine whether the data on pulse rate was statistically significant, the data was analyzed using repeated-measures analysis of variance. The result is presented in table 4.2.2a.

Table 4.2.2a: Repeated-measures analysis of variance on pulse rate of amateur male endurance runners at low-altitude and near sea level

Low-altitude	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	238.229	3	79.410	401.869	.000
	Greenhouse-Geisser	238.229	1.360	175.200	401.869	.000
	Huyn8h-Feldt	238.229	1.485	160.409	401.869	.000
	Lower-bound	238.229	1.000	238.229	401.869	.000
Error	Sphericity Assumed	6.521	33	.198		
(Duration)	Greenhouse-Geisser	6.521	14.957	.436		
	Huynh-Feldt	6.521	16.336	.399		
	Lower-bound	6.521	11.000	.593		
Near Sea Level						
Duration	Sphericity Assumed	295.167	3	98.389	974.050	.000
	Greenhouse-Geisser	295.167	1.600	184.479	974.050	.000
	Huynh-Feldt	295.167	1.830	161.312	974.050	.000
	Lower-bound	295.167	1.000	295.167	974.050	.000
Error	Sphericity Assumed	3.333	33	.101		
(Duration)	Greenhouse-Geisser	3.333	17.600	.189		
	Huynh-Feldt	3.333	20.128	.166		
	Lower-bound	3.333	11.000	.303		

Table 4.2.2a shows the results of the repeated measures analysis of variance on pulse rate of amateur endurance runners at low-altitude and near sea level. An observation of the analysis revealed that the duration of training at low-altitude caused statistically significant effect on pulse rate of the participants ($p = 0.000$). The training at near sea level also caused significant reduction on pulse rate of the participants ($p = 0.000$). These observations are confirmed by the significant value of p, which is less than 0.05. Therefore, the null hypothesis which states that there are no significant effects of low-altitude and near

sea level training on pulse rate of male amateur endurance runners of Bauchi State, Nigeria was rejected.

The graphic illustration of the reduction in pulse rate at low-altitude and near sea-level is presented in figure 4.2.2

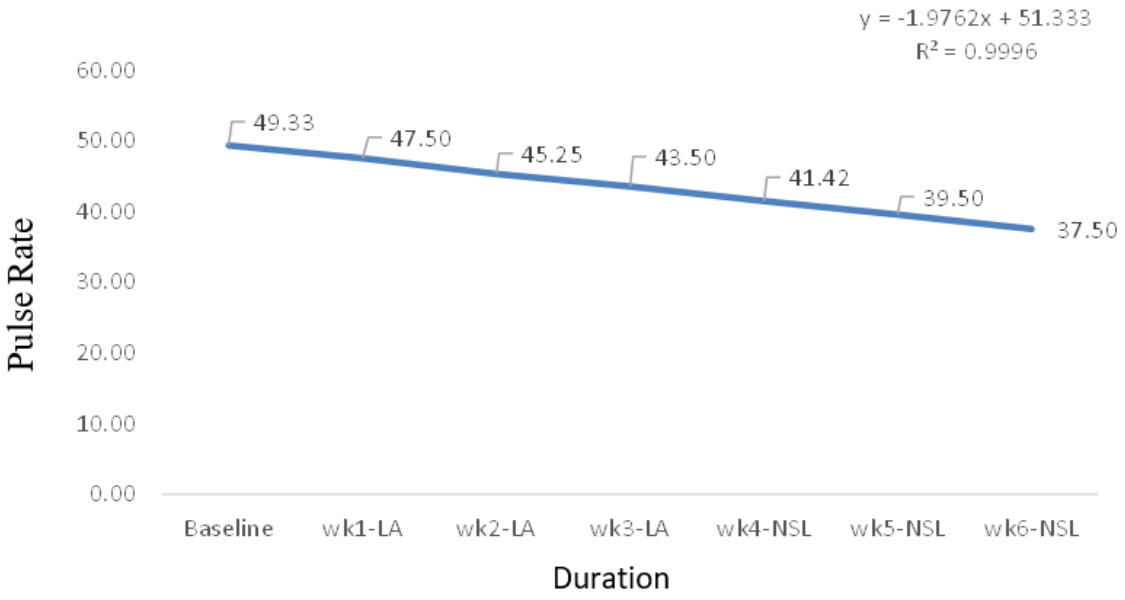


Figure 4.2.2: Graphic illustration of pulse rate of the participants at low-altitude and near sea level

An observation of the graph showed a gradual and consistent reduction in the pulse rate of the participants at both low-altitude and near-sea-level, which may be attributed to the training period. The predicted sustained reduction in pulse rate is indicated by $R^2 = 0.9996$

However, to assess the sustained effects of the contribution of low-altitude and near sea-level training on the pulse rate of male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyze the data. The result is presented in table 4.2.2b

Table 4.2.2b: Summary of Simple Linear Regression Analysis on the sustained effects of low-altitude and near sea level training on pulse rate of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.751[a]	0.564	0.558	3.521

a. Predictors: (Constant), Pulse rate

Model		Sum of Squares	Df	Mean Square	F	*p-value*
	Between groups	1312.738	6	218.79	16.584	0.00
	Within groups	1015.833	77	13.193		
	Total	2328.571	83			

Dependent Variable: Pulse rate	B	Std. Error	T	Sig.
(Constant)	51.333	0.859	59.763	0.000
Weekly Training in LA and NSL	-1.976	0.192	-10.289	0.000

Table 4.2.2b shows the simple linear regression analysis on the sustained effects of low-altitude and near-sea-level training on pulse rate of male amateur endurance runners of Bauchi State, Nigeria. The results revealed that there was a sustained effect of low-altitude exposure on pulse rate on return to near-sea-level of male amateur endurance runners of Bauchi State, Nigeria ($F = 16.584$, $R = 0.751$, $R^2=0.564$ and Adjusted R square = 0.558). The findings further revealed that the effects of low-altitude training on pulse rate was sustained at near-sea-level within three weeks among male amateur endurance runners ($p = 0.000$).

To determine the phases of training that was responsible for the significant effect, post-hoc least square difference (LSD) test for multiple comparison was applied on the data at baseline, 1st, 2nd and 3rd weeks of training at low-altitude and near sea level was analyzed and the results is presented in table 4.2.2c

Table 4.2.2c: Results of LSD post-hoc test on pulse rate of amateur endurance runners at low-altitude and near sea level

	(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Low-altitude	Baseline	Week 1	1.917*	.083	.000	1.733	2.100
		Week 2	4.083*	.149	.000	3.756	4.411
		Week 3	5.917*	.260	.000	5.345	6.489
	Week 1	Baseline	-1.917*	.083	.000	-2.100	-1.733
		Week 2	2.167*	.112	.000	1.919	2.414
		Week 3	4.000*	.246	.000	3.458	4.542
	Week 2	Baseline	-4.083*	.149	.000	-4.411	-3.756
		Week 1	-2.167*	.112	.000	-2.414	-1.919
		Week 3	1.833*	.167	.000	1.467	2.200
	Week 3	Baseline	-5.917*	.260	.000	-6.489	-5.345
		Week 1	-4.000*	.246	.000	-4.542	-3.458
		Week 2	-1.833*	.167	.000	-2.200	-1.467
	(I) Duration	**(J) Duration**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval for Difference[b]**	
						Lower Bound	**Upper Bound**
Near Sea Level	Baseline	Week 1	2.000	.000	.	2.000	2.000
		Week 2	4.417*	.149	.000	4.089	4.744
		Week 3	6.583*	.149	.000	6.256	6.911
	Week 1	Baseline	-2.000	.000	.	-2.000	-2.000
		Week 2	2.417*	.149	.000	2.089	2.744
		Week 3	4.583*	.149	.000	4.256	4.911
	Week 2	Baseline	-4.417*	.149	.000	-4.744	-4.089
		Week 1	-2.417*	.149	.000	-2.744	-2.089
		Week 3	2.167*	.112	.000	1.919	2.414
	Week 3	Baseline	-6.583*	.149	.000	-6.911	-6.256
		Week 1	-4.583*	.149	.000	-4.911	-4.256
		Week 2	-2.167*	.112	.000	-2.414	-1.919

An observation of table 4.2.2c showed that there was significant reduction in the participants' pulse rate immediately after the 1st 2nd and 3rd week (p = 0.000) at low-altitude and near sea level.

Hypothesis 2 There are no significant effects of low-altitude and near sea-level training on haematocrit (HCT) of male amateur endurance runners of Bauchi State, Nigeria.

To determine whether the data collected was significant, it was analyzed using repeated measures analysis of variance and the result is presented in table 4:2:3a.

Table 4.2.3a: Repeated measures analysis of variance on haematocrit (HCT) of amateur male endurance runners at low-altitude and near sea level

Low-altitude	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	349.583	3	116.528	19.830	.000
	Greenhouse-Geisser	349.583	1.226	285.100	19.830	.000
	Huynh-Feldt	349.583	1.301	268.737	19.830	.000
	Lower-bound	349.583	1.000	349.583	19.830	.001
Error (Duration)	Sphericity Assumed	193.917	33	5.876		
	Greenhouse-Geisser	193.917	13.488	14.377		
	Huynh-Feldt	193.917	14.309	13.552		
	Lower-bound	193.917	11.000	17.629		
Near Sea Level						
Duration	Sphericity Assumed	17.396	3	5.799	2.539	0.073
	Greenhouse-Geisser	17.396	1.064	16.351	2.539	0.137
	Huynh-Feldt	17.396	1.084	16.054	2.539	0.136
	Lower-bound	17.396	1.000	17.396	2.539	0.139
Error (Duration)	Sphericity Assumed	75.354	33	2.283		
	Greenhouse-Geisser	75.354	11.703	6.439		
	Huynh-Feldt	75.354	11.920	6.322		
	Lower-bound	75.354	11.000	6.850		

Table 4.2.3a shows repeated-measures analysis of variance on haematocrit of male amateur endurance runners at low-altitude and near sea level. An observation of the table revealed that training caused significant increase of haematocrit of the participants at low-altitude *(p* = 0.000). However, training at near sea level did not caused significant increase on the haematocrit (*p* = 0.137). Therefore, the null hypothesis which states that there are no significant effects of low-altitude and near sea level training on haematocrit of male

amateur endurance runners of Bauchi State, Nigeria. was rejected for low altitude exposure and retained for near sea level training.

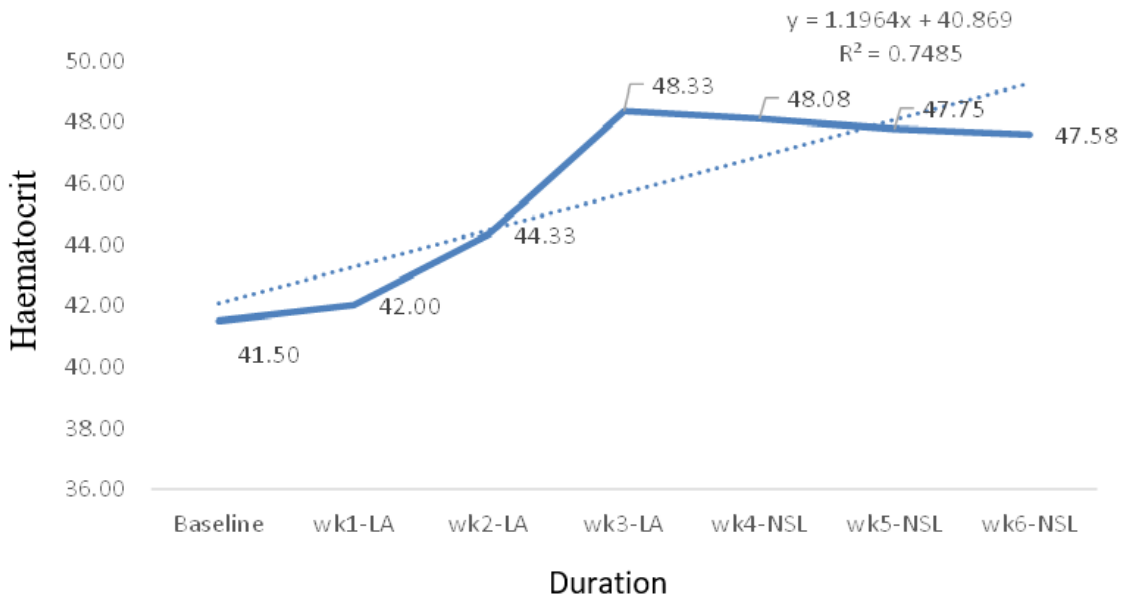


Figure 4.2.3 shows the graphic line of the haematocrit levels of the participants at low-altitude and near sea level. An observation of the data showed that there was marked increase in the haematocrit levels of the participants from the base-line to third week. The graphic line further showed that on arrival at low-altitude, haematocrit production was stimulated; which might have caused the positive adaptation to training throughout the period of stay. However, on arrival at near sea level, the peaked haematocrit level stabilized for two weeks and declined towards the end of the third week.

To assess the sustained effect of low-altitude adaptation of the haematocrit level on return to near sea-level among male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyze the data. The result is presented in table 4.2.3b

Table 4.2.3b: Summary of Simple Linear Regression Analysis on the sustainability of haematocrit levels at near sea-level training of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
	.358[a]	0.128	0.118	6.307

a. Predictors: (Constant), Haematocrit

Model	Sum of Squares	Df	Mean Square	F	*p-value*
Between groups	642.571	6	107.095	2.66	0.021
Within groups	3100.417	77	40.265		
Total	3742.988	83			

Dependent Variable: HCT	B	Std. Error	T	Sig.
(Constant)	40.869	1.539	26.559	0.000
Weekly Training in LA and NSL	1.196	0.344	3.477	0.001

Table 4.2.3b shows the simple linear regression analysis on the sustainability of haematocrit levels after low-altitude exposure and return to near sea level of male amateur endurance runners of Bauchi State, Nigeria. The results revealed that on return to near-sea-level, haematocrit levels of the participants was sustained above the values achieved at low altitude (F = 2.66, R = 0358, R^2=0.128 and Adjusted R square = 0.118). The findings further revealed that the effect of low-altitude training on haematocrit levels was sustained at near-sea-level within three weeks among male amateur endurance runners (p = 0.001).

To determine the phases of training that was responsible for the significant effect, post-hoc least square difference (LSD) test for multiple comparison was applied on the data

at baseline, 1st, 2nd and 3rd weeks of training at low-altitude and near sea level and the results is presented in table 4.2.3c

Table 4.2.3c: Results of LSD *post-hoc* tests on haematocrit of amateur endurance runners at low-altitude

	(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference Lower Bound	Upper Bound
Low-altitude	Baseline	Week 1	-.500*	.151	.007	-.832	-.168
		Week 2	-2.833*	.601	.001	-4.156	-1.511
		Week 3	-6.833*	1.403	.000	-9.920	-3.746
	Week 1	Baseline	.500*	.151	.007	.168	.832
		Week 2	-2.333*	.582	.002	-3.614	-1.053
		Week 3	-6.333*	1.411	.001	-9.438	-3.229
	Week 2	Baseline	2.833*	.601	.001	1.511	4.156
		Week 1	2.333*	.582	.002	1.053	3.614
		Week 3	-4.000*	1.094	.004	-6.408	-1.592
	Week 3	Baseline	6.833*	1.403	.000	3.746	9.920
		Week 1	6.333*	1.411	.001	3.229	9.438
		Week 2	4.000*	1.094	.004	1.592	6.408

Table 4.2.3c shows that the significant increase in the participants haematocrit levels occurred immediately after the 1st, 2nd and 3rd week at low altitude. This showed that on arrival at low-altitude, haematocrit production was stimulated.

Hypothesis 3: There are no significant effects of low-altitude and near sea-level training on respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria.

To determine whether the data on respiratory frequency was statistically significant, it was analyzed using repeated measures analysis of variance, the result is presented on table 4.2.4a.

Table 4.2.4a: Repeated measures analysis of variance on respiratory frequency of male amateur endurance runners at low-altitude and near sea level

Low-altitude	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	285.562	3	95.187	247.581	.000
	Greenhouse-Geisser	285.562	2.345	121.765	247.581	.000
	Huynh-Feldt	285.562	3.000	95.187	247.581	.000
	Lower-bound	285.562	1.000	285.562	247.581	.000
Error (Duration)	Sphericity Assumed	12.687	33	.384		
	Greenhouse-Geisser	12.687	25.797	.492		
	Huynh-Feldt	12.687	33.000	.384		
	Lower-bound	12.687	11.000	1.153		
Near Sea Level						
Duration	Sphericity Assumed	353.229	3	117.743	484.429	.000
	Greenhouse-Geisser	353.229	1.829	193.087	484.429	.000
	Huynh-Feldt	353.229	2.176	162.352	484.429	.000
	Lower-bound	353.229	1.000	353.229	484.429	.000
Error (Duration)	Sphericity Assumed	8.021	33	.243		
	Greenhouse-Geisser	8.021	20.123	.399		
	Huynh-Feldt	8.021	23.933	.335		
	Lower-bound	8.021	11.000	.729		

Table 4.2.4a shows the results of repeated measures analysis of variance on respiratory frequency of male amateur endurance runners at low-altitude and near sea level. Observation of the table revealed that training caused significant effect on the respiratory frequency of the participants at both low-altitude ($p = 0.000$) and near sea level ($p = 0.000$). Therefore, the null hypothesis which states that there are no significant effects of low-altitude and near sea level training on respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria, was rejected.

The graphic illustration of the reduction in respiratory frequency at low-altitude and near sea-level is presented in figure 4.2.4

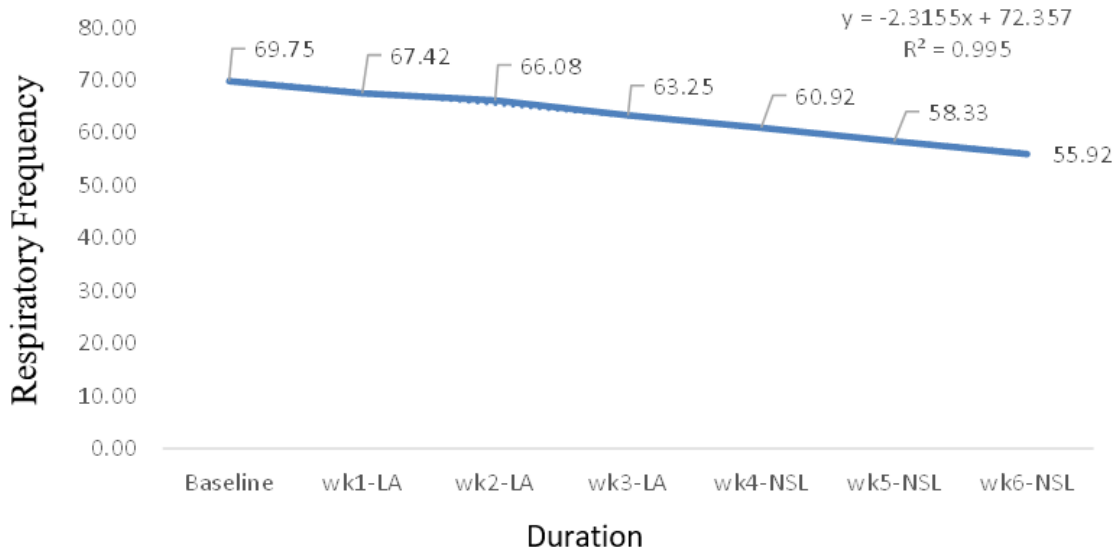


Figure 4.2.4: Graphic illustration of respiratory frequency of the participants at low-altitude and near sea level

An observation of the results revealed marked reduction in the respiratory frequency (RF) of the participants, which may be attributed to positive adaptive responses of the respiratory mechanisms to training at low altitude. The predicted influence is $R^2 = 0.995$. this reduction was sustained even on return to near sea level.

To assess the sustained effect of low-altitude on RF adaptation on return to near sea-level among male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyze the data. The results is presented in table 4:2:4b

Table 4.2.4b: Summary of Simple Linear Regression Analysis on the sustained - effects of low altitude and near sea-level training on the respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.807[a]	0.652	0.648	3.425

a. Predictors: (Constant), Respiratory frequency

Model		Sum of Squares	Df	Mean Square	F	*p-value*
1	Between groups	1810.405	6	301.734	24.384	0.000
	Within groups	952.833	77	12.374		
	Total	2763.238	83			

Dependent Variable: RF	B	Std. Error	T	Sig.
(Constant)	72.357	0.836	86.597	0.000
Weekly Training in LA and NSL	-2.315	0.187	-12.393	0.000

Table 4.2.4b: shows the simple linear regression analysis on the effects of contribution of low-altitude and near-sea-level training on respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria. The results revealed that low-altitude and near-sea-level training had sustained reduction on the respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria ($F = 24.384$, $R = .807$, $R^2=0.652$ and Adjusted R square = 0.648). The findings further revealed that the effect of low-altitude training on respiratory frequency was sustained at near-sea-level within three weeks among male amateur endurance runners ($p = 0.000$).

To determine the phases of training that was responsible for the significant effects, post-hoc least square difference (LSD) test for multiple comparison was applied on the data at baseline, 1st, 2nd and 3rd weeks of training at low-altitude and near sea level was analyzed and the results is presented in table 4.2.4c.

Table 4.2.4c: Results of LSD *post-hoc* tests on respiratory frequency of amateur endurance runners at low-altitude and near sea level

	(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Low-altitude	Baseline	Week 1	1.667*	.256	.000	1.103	2.231
		Week 2	4.167*	.241	.000	3.636	4.697
		Week 3	6.417*	.288	.000	5.784	7.050
	Week 1	Baseline	-1.667*	.256	.000	-2.231	-1.103
		Week 2	2.500*	.151	.000	2.168	2.832
		Week 3	4.750*	.305	.000	4.080	5.420
	Week 2	Baseline	-4.167*	.241	.000	-4.697	-3.636
		Week 1	-2.500*	.151	.000	-2.832	-2.168
		Week 3	2.250*	.250	.000	1.700	2.800
	Week 3	Baseline	-6.417*	.288	.000	-7.050	-5.784
		Week 1	-4.750*	.305	.000	-5.420	-4.080
		Week 2	-2.250*	.250	.000	-2.800	-1.700
	(I) Duration	**(J) Duration**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval for Difference**	
						Lower Bound	**Upper Bound**
Near Sea Level	Baseline	Week 1	2.417*	.149	.000	2.089	2.744
		Week 2	4.667*	.188	.000	4.253	5.081
		Week 3	7.333*	.284	.000	6.708	7.959
	Week 1	Baseline	-2.417*	.149	.000	-2.744	-2.089
		Week 2	2.250*	.131	.000	1.963	2.537
		Week 3	4.917*	.229	.000	4.413	5.420
	Week 2	Baseline	-4.667*	.188	.000	-5.081	-4.253
		Week 1	-2.250*	.131	.000	-2.537	-1.963
		Week 3	2.667*	.188	.000	2.253	3.081
	Week 3	Baseline	-7.333*	.284	.000	-7.959	-6.708
		Week 1	-4.917*	.229	.000	-5.420	-4.413
		Week 2	-2.667*	.188	.000	-3.081	-2.253

Table 4.2.4c showed that the significant decrease in respiratory frequency occurred immediately after 1st 2nd and 3rd week at both low-altitude and near sea level.

Hypothesis 4: There are no significant effects of low-altitude training and near-sea level training on VO_2max of male amateur endurance runners of Bauchi State, Nigeria.

To determine whether VO_2max data was statistically significant, it was analyzed using repeated measures analysis of variance and the result is presented in table 4.2.5a.

Table 4.2.5a: Repeated measures analysis of variance on VO_2max of amateur male endurance runners at low-altitude and near sea level

Low-altitude Source		Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	822.910	3	274.303	119.001	.000
	Greenhouse-Geisser	822.910	1.337	615.717	119.001	.000
	Huynh-Feldt	822.910	1.453	566.472	119.001	.000
	Lower-bound	822.910	1.000	822.910	119.001	.000
Error (Duration)	Sphericity Assumed	76.067	33	2.305		
	Greenhouse-Geisser	76.067	14.702	5.174		
	Huynh-Feldt	76.067	15.980	4.760		
	Lower-bound	76.067	11.000	6.915		
Near Sea Level						
Duration	Sphericity Assumed	519.523	3	173.174	77.793	.000
	Greenhouse-Geisser	519.523	1.121	463.393	77.793	.000
	Huynh-Feldt	519.523	1.159	448.098	77.793	.000
	Lower-bound	519.523	1.000	519.523	77.793	.000
Error (Duration)	Sphericity Assumed	73.461	33	2.226		
	Greenhouse-Geisser	73.461	12.332	5.957		
	Huynh-Feldt	73.461	12.753	5.760		
	Lower-bound	73.461	11.000	6.678		

Table 4.2.5a shows repeated-measures analysis of variance on VO_2max of male amateur endurance runners at low-altitude and near sea level. An observation of the table revealed that training caused significant improvement on VO_2max of the participants at both low altitude (p = 0.000) and near sea level (p = 0.000). Therefore, the null hypothesis which states that there are no significant effect of low-altitude training and near sea level training on VO_2max of male amateur endurance runners of Bauchi State, Nigeria. was rejected.

The graphic illustration of the improvement in VO_2max at low-altitude and near sea-level is presented in figure 4.2.5

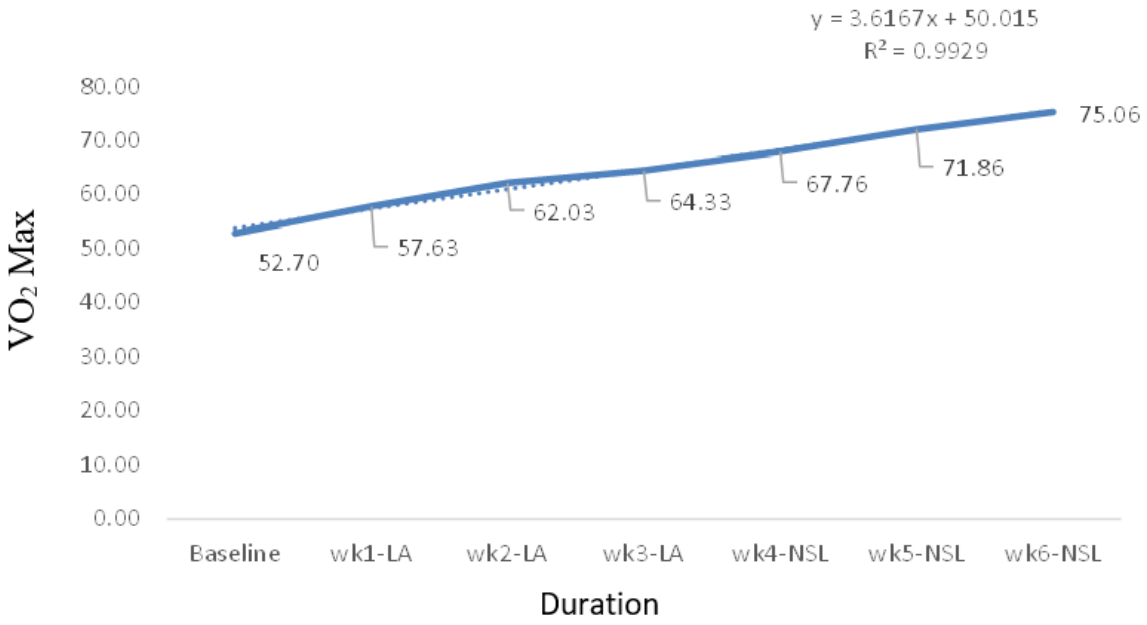


Figure 4.2.5: Graphic illustration of VO_2max of the participants at low-altitude and near sea level

Figure 4.2.5 showed that VO_2max of the participants at low-altitude and near sea level improved according to duration of training ($R^2 = 0.992$).

To establish the sustained effects of low-altitude and near sea-level on the VO_2max of male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyzed the data. The result is presented in table 4.2.5b

Table 4.2.5b: Summary of Simple Linear Regression Analysis on the sustained effects of low-altitude and near sea-level training on VO2max levels of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.644[a]	0.415	0.408	8.689128

a. Predictors: (Constant), VO_2max

Model		Sum of Squares	Df	Mean Square	F	*p-value*
1	Between groups	4426.242	6	737.707	9.222	0.000
	Within groups	6159.866	77	79.998		
	Total	10586.108	83			

Dependent Variable: VO_2max	B	Std. Error	T	Sig.
(Constant)	50.015	2.12	23.593	0.000
Weekly Training in LA and NSL	3.617	0.474	7.63	0.000

Table 4.2.5b shows the simple linear regression analysis on the sustained effects of low-altitude and near-sea-level training on VO_2max of male amateur endurance runners of Bauchi State, Nigeria. The results revealed that the effect of low-altitude training on VO_2max was sustained at near-sea-level within three weeks among male amateur endurance runners ($F = 9.222$, $R = .644^a$, $R^2=0.415$ and Adjusted R square = 0.408).

To determine the phases of training that was responsible for the significant effect, post-hoc least square difference (LSD) test for multiple comparison was applied on the data at baseline, 1st, 2nd and 3rd weeks of training at low-altitude and near sea level was analyzed and the results is presented in table 4.2.5c

Table 4.2.5c: Results of LSD post-hoc test on VO_2max of amateur distance runners at low-altitude and near sea level

	(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Low-altitude	Baseline	Week 1	-2.983*	.420	.000	-3.907	-2.060
		Week 2	-7.499*	.722	.000	-9.088	-5.911
		Week 3	-10.803*	.946	.000	-12.886	-8.720
	Week 1	Baseline	2.983*	.420	.000	2.060	3.907
		Week 2	-4.516*	.447	.000	-5.499	-3.533
		Week 3	-7.820*	.584	.000	-9.105	-6.534
	Week 2	Baseline	7.499*	.722	.000	5.911	9.088
		Week 1	4.516*	.447	.000	3.533	5.499
		Week 3	-3.304*	.414	.000	-4.216	-2.392
	Week 3	Baseline	10.803*	.946	.000	8.720	12.886
		Week 1	7.820*	.584	.000	6.534	9.105
		Week 2	3.304*	.414	.000	2.392	4.216
	(I) Duration	**(J) Duration**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval for Difference**	
						Lower Bound	**Upper Bound**
Near Sea Level	Baseline	Week 1	-2.421*	.186	.000	-2.831	-2.011
		Week 2	-5.588*	.584	.000	-6.873	-4.304
		Week 3	-8.735*	.935	.000	-10.794	-6.676
	Week 1	Baseline	2.421*	.186	.000	2.011	2.831
		Week 2	-3.167*	.431	.000	-4.116	-2.217
		Week 3	-6.313*	.775	.000	-8.018	-4.609
	Week 2	Baseline	5.588*	.584	.000	4.304	6.873
		Week 1	3.167*	.431	.000	2.217	4.116
		Week 3	-3.147*	.436	.000	-4.105	-2.188
	Week 3	Baseline	8.735*	.935	.000	6.676	10.794
		Week 1	6.313*	.775	.000	4.609	8.018
		Week 2	3.147*	.436	.000	2.188	4.105

Table 4.2.5c shows that the significant increase in VO_2max occurred immediately after the 1st, 2nd, and 3rd week at both low-altitude and near sea level.

Hypothesis 5: There are no significant effects of low-altitude training and near sea level

training on potassium level of male amateur endurance runners of Bauchi State

To determine whether the data collected on potassium was significant, it was analyzed using repeated measures analysis of variance and the result is presented in table 4.2.6a.

Table 4.2.6a: Repeated measures analysis of variance on potassium of amateur male endurance runners at low-altitude and near sea level

Low-altitude	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	3.052	3	1.017	2.913	.049
	Greenhouse-Geisser	3.052	2.246	1.359	2.913	.068
	Huynh-Feldt	3.052	2.850	1.071	2.913	.052
	Lower-bound	3.052	1.000	3.052	2.913	.116
Error	Sphericity Assumed	11.523	33	.349		
(Duration)	Greenhouse-Geisser	11.523	24.705	.466		
	Huynh-Feldt	11.523	31.352	.368		
	Lower-bound	11.523	11.000	1.048		
Near Sea Level						
Duration	Sphericity Assumed	8.824	3	2.941	11.479	.000
	Greenhouse-Geisser	8.824	2.077	4.249	11.479	.000
	Huynh-Feldt	8.824	2.568	3.436	11.479	.000
	Lower-bound	8.824	1.000	8.824	11.479	.006
Error	Sphericity Assumed	8.456	33	.256		
(Duration)	Greenhouse-Geisser	8.456	22.843	.370		
	Huynh-Feldt	8.456	28.253	.299		
	Lower-bound	8.456	11.000	.769		

Table 4.2.6a shows the result of the repeated-measures analysis of variance on the potassium of male amateur endurance runners at low-altitude and near sea level. Observation of the table revealed that the duration of training at low-altitude did not caused statistically significant effect on potassium of the participants (p = 0.068). However, training at near sea level caused significant effect on potassium (p = 0.000). Therefore, the null hypothesis which states that there are no significant effects of low-altitude and near sea level training on potassium of male amateur endurance runners of Bauchi State, Nigeria. was retained for low-altitude and rejected for near sea level training.

The graphic illustration of potassium level at low-altitude and near sea-level is presented in figure 4.2.6

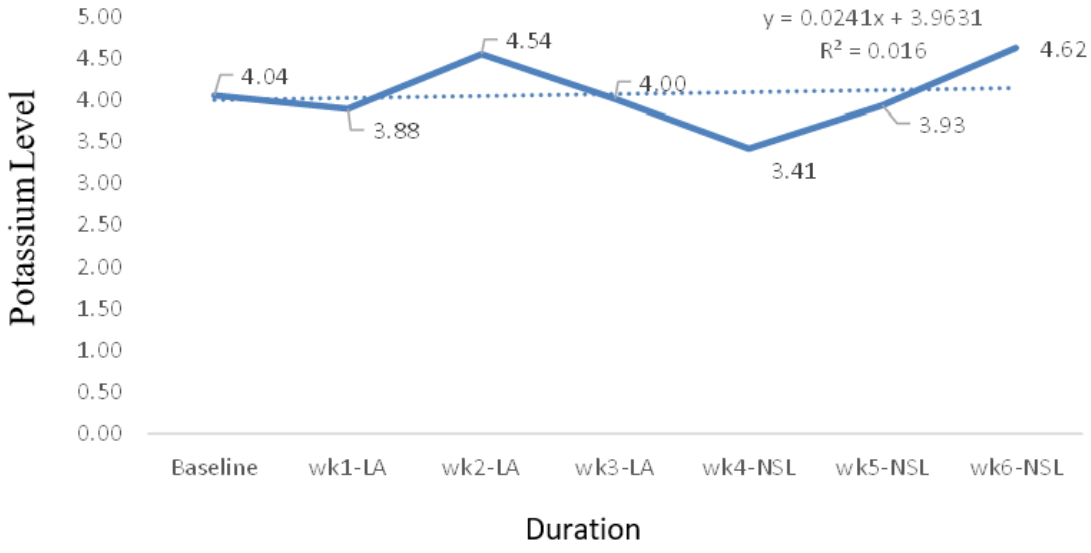


Figure 4.2.6: Graphic illustration of potassium level of the participants at low-altitude and near sea level

An observation of the graphic line showed inconsistent potassium level among the participants which might be due to low dietary potassium intake, dehydration or radiation at low altitude ($R^2 = 0.016$). Even at near sea level, the graphic line was inconsistent but became significant after the 2nd week.

However, to assess the sustained effects of low-altitude and near sea-level on the potassium level of male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyze the data. The result is presented in table 4.2.6b

Table 4.2.6b: Summary of Simple Linear Regression Analysis on the sustained effects low-altitude and near sea-level training on potassium level of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.073[a]	0.005	-0.007	0.6638

a. Predictors: (Constant), Potassium

Model		Sum of Squares	Df	Mean Square	F	*p-value*
1	Between groups	12.239	6	2.04	6.522	0.000
	Within groups	24,083	77	0.313		
	Total	36.322	83			

Dependent Variable: K	B	Std. Error	T	Sig.
(Constant)	3.963	0.162	24.473	0.000
Weekly Training in LA and NSL	0.024	0.036	0.666	0.507

Table 4.2.6b shows the simple linear regression analysis on the sustained effects of low-altitude and near-sea-level training on potassium level of male amateur endurance runners of Bauchi State, Nigeria. The result revealed that low-altitude had no significant effect on potassium level of male amateur endurance runners of Bauchi State, Nigeria ($F = 6.522$, $R = .073^a$, $R^2=0.005$ and Adjusted R square = -0.007). However, potassium level improved after the 2nd and 3rd week on return to near-sea-level among male amateur endurance runners ($p = 0.000$).

To determine the phases of training that was responsible for the significant effect, post-hoc least square difference (LSD) test for multiple comparison was applied on the data at baseline, 1st, 2nd and 3rd weeks of training at near sea level was analyzed and the results is presented in table 4.2.6c

Table 4.2.6c: Results of LSD *post-hoc* tests on K of amateur distance runners at low-altitude and near sea level

	(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
						Lower Bound	Upper Bound
Near Sea Level	Baseline	Week 1	.592*	.253	.039	.035	1.149
		Week 2	.075	.249	.769	-.473	.623
		Week 3	-.617*	.245	.028	-1.155	-.078
	Week 1	Baseline	-.592*	.253	.039	-1.149	-.035
		Week 2	-.517*	.123	.001	-.787	-.246
		Week 3	-1.208*	.174	.000	-1.592	-.825
	Week 2	Baseline	-.075	.249	.769	-.623	.473
		Week 1	.517*	.123	.001	.246	.787
		Week 3	-.692*	.158	.001	-1.039	-.344
	Week 3	Baseline	.617*	.245	.028	.078	1.155
		Week 1	1.208*	.174	.000	.825	1.592
		Week 2	.692*	.158	.001	.344	1.039

Table 4.2.6c shows that improvement in potassium level occurred between baseline 2nd and 3rd week at near sea level

Hypothesis 6: There are no significant effects of low-altitude training and near sea level training on sodium of male amateur endurance runners of Bauchi State

To determine whether the data collected on sodium was statistically significant, it was analyzed using repeated measures analysis of variance and the result is presented in table 4.2.7a.

Table 4.2.7a: Repeated measures analysis of variance on sodium of amateur male endurance runners at low-altitude and near sea level

Low-altitude	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	176.945	3	58.982	1.619	.204
	Greenhouse-Geisser	176.945	2.396	73.852	1.619	.214
	Huynh-Feldt	176.945	3.000	58.982	1.619	.204
	Lower-bound	176.945	1.000	176.945	1.619	.229
Error (Duration)	Sphericity Assumed	1202.040	33	36.425		
	Greenhouse-Geisser	1202.040	26.355	45.609		
	Huynh-Feldt	1202.040	33.000	36.425		
	Lower-bound	1202.040	11.000	109.276		
Near Sea Level						
Duration	Sphericity Assumed	299.192	3	99.731	3.104	.040
	Greenhouse-Geisser	299.192	2.026	147.674	3.104	.064
	Huynh-Feldt	299.192	2.486	120.334	3.104	.051
	Lower-bound	299.192	1.000	299.192	3.104	.106
Error (Duration)	Sphericity Assumed	1060.365	33	32.132		
	Greenhouse-Geisser	1060.365	22.286	47.579		
	Huynh-Feldt	1060.365	27.350	38.770		
	Lower-bound	1060.365	11.000	96.397		

Table 4.2.7a shows the result of the repeated-measures analysis of variance on sodium level of male amateur endurance runners at low-altitude and near sea level. Observation of the analysis revealed that the duration of training did not caused significant effect on sodium of the participants at altitude (p = 0.214) and near sea level (p = 0.064). Therefore, the null hypothesis which states that there are no significant effect of low-altitude and near sea level training on sodium level of male amateur endurance runners of Bauchi State, Nigeria was retained.

The graphic illustration of sodium level at low-altitude and near sea-level is presented in figure 4.2.7

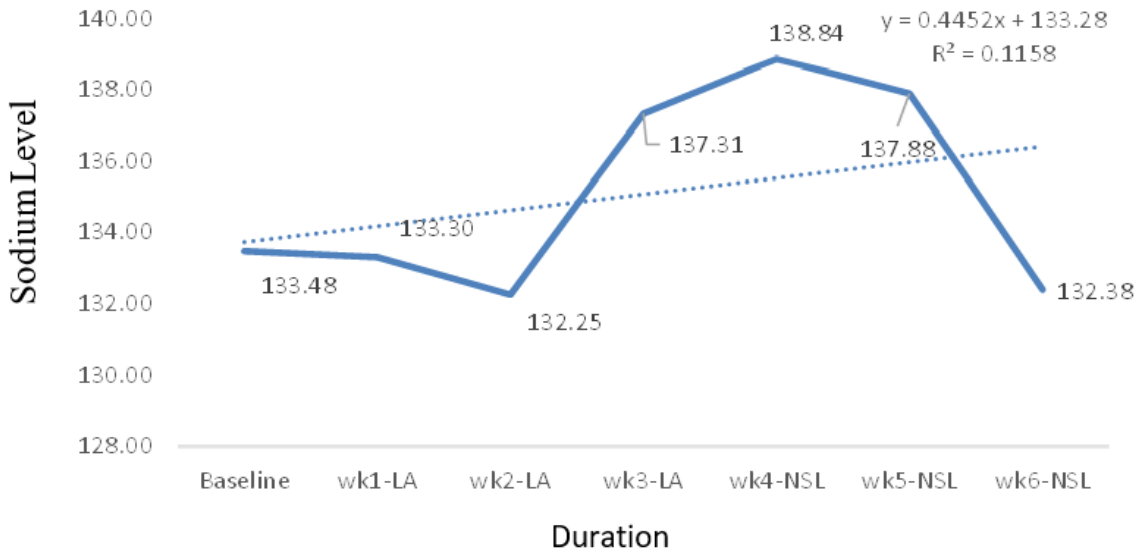


Figure 4.2.7: Graphic illustration of sodium level of the participants at low-altitude and near sea level

An observation of the graphic line showed a marked decline in sodium level within the first two (2) weeks but peaked at the end of the third (3^{rd}) week among the participants. The initial decline in sodium might be attributed to low dietary sodium intake, dehydration or radiation at low-altitude ($R^2 = 0.01158$); while the peaked level attained at the end of the third week might be as a result of adaptive responses to the environment

To determine the sustained effects of low-altitude and near sea-level on the sodium level of male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyze the data. The result is presented in table 4.2.7b

Table 4.2.7b: Summary of Simple Linear Regression Analysis on the sustained effects of low-altitude and near sea-level training on sodium level of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.157[a]	0.025	0.013	5.6572

a. Predictors: (Constant), sodium

Model		Sum of Squares	Df	Mean Square	F	*p-value*
1	Between groups	575.408	6	96.901	3.491	0.004
	Within groups	2115.55	77	27.475		
	Total	2690.958	83			

Dependent Variable: NA	B	Std. Error	T	Sig.
(Constant)	133.281	1.38	96.565	0.000
Weekly Training in LA and NSL	0.445	0.309	1.443	0.153

Table 4.2.7b shows the simple linear regression analysis on the sustained effect of low-altitude exposure on return to near-sea level training on sodium of male amateur endurance runners of Bauchi State, Nigeria. The result revealed that low-altitude training had no effect on sodium level of the participants (F = 3.491, R = .0157[a], R^2=0.025 and Adjusted R square = -0.013). However, on return to near sea level, sodium variability increased (F = 0.000); which might be explained by improved hydration, environmental condition or diet.

Hypothesis 7: There are no significant effects of low-altitude and near sea level training on speed endurance of male amateur endurance runners of Bauchi State

To determine whether speed endurance data was statistically significant, the data was analyzed using repeated measures analysis of variance, the result is presented on table 4.2.8a.

Table 4.2.8a: Repeated measures analysis of variance on speed endurance (SEN) of amateur male endurance runners at low-altitude and near sea level

Low-altitude	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Duration	Sphericity Assumed	88.110	3	29.370	18.923	.000
	Greenhouse-Geisser	88.110	1.598	55.153	18.923	.000
	Huynh-Feldt	88.110	1.826	48.248	18.923	.000
	Lower-bound	88.110	1.000	88.110	18.923	.001
Error	Sphericity Assumed	51.217	33	1.552		
(Duration)	Greenhouse-Geisser	51.217	17.573	2.915		
	Huynh-Feldt	51.217	20.088	2.550		
	Lower-bound	51.217	11.000	4.656		
Near sea level						.
Duration	Sphericity Assumed	66.481	3	22.160	29.970	.000
	Greenhouse-Geisser	66.481	2.400	27.705	29.970	.000
	Huynh-Feldt	66.481	3.000	22.160	29.970	.000
	Lower-bound	66.481	1.000	66.481	29.970	.000
Error	Sphericity Assumed	24.401	33	.739		
(Duration)	Greenhouse-Geisser	24.401	26.395	.924		
	Huynh-Feldt	24.401	33.000	.739		
	Lower-bound	24.401	11.000	2.218		

Table 4.2.8a shows the result of repeated-measures analysis of variance on speed endurance of male amateur endurance runners at low-altitude and near sea level. An observation of the table revealed that the duration of training caused significant increase on speed endurance of the participants at both low-altitude (p = 0.000) and near sea level (p =0.000). Therefore, the null hypothesis which states that there are no significant effects of low-altitude and near sea level training on speed endurance of male amateur endurance runners of Bauchi State, Nigeria. was rejected.

The graphic illustration of the improvement in speed endurance at low-altitude and near sea-level is presented in figure 4.2.8

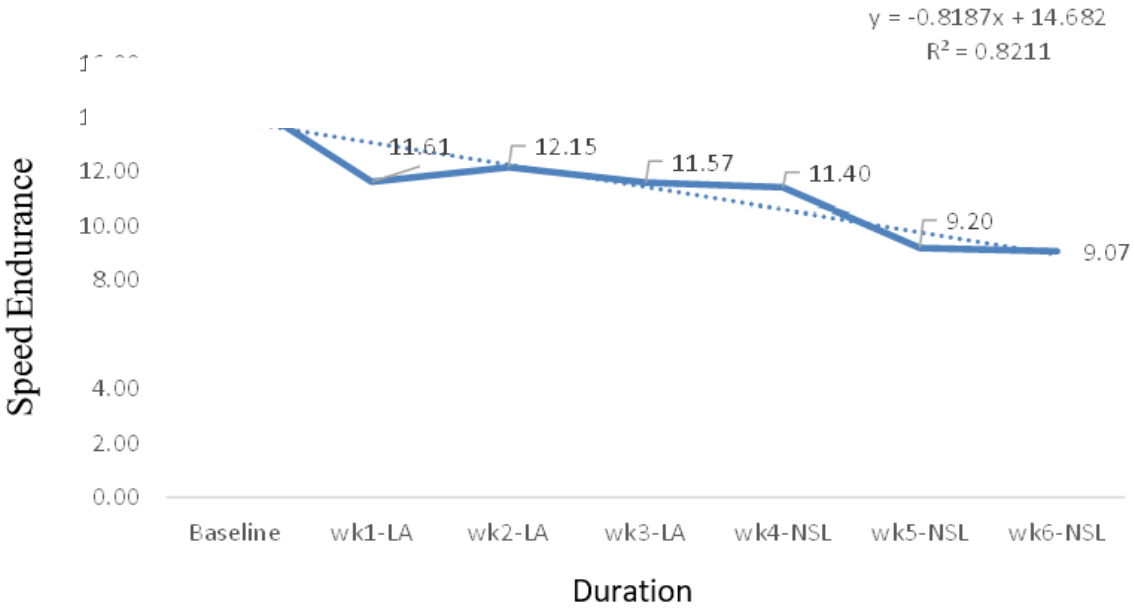


Figure 4.2.8: Graphic illustration of speed endurance of the participants at low-altitude and near sea level. An observation of the graphic line showed that speed endurance of the participants improved progressively through the periods of training at low-altitude and near sea level. The improvement in speed endurance of the participants may be attributed to adaption to the environment and the training loads. The predicted sustained effect is indicated by $R^2 = 0.8211$.

To assess the sustained effect of low-altitude and near sea-level on the speed endurance of male amateur endurance runners of Bauchi, the simple linear regression analysis was used to analyze the data. The result is presented in table 4.2.8b

Table 4.2.8b: Summary of Simple Linear Regression Analysis on the sustained effect of low-altitude on return to near sea-level training on speed endurance of male amateur endurance runners of Bauchi State, Nigeria.

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.735[a]	0.539	0.534	1.53105

a. Predictors: (Constant), speed endurance

Model		Sum of Squares	Df	Mean Square	F	*p-value*
1	Between groups	274.257	6	45.71	24.587	0.000
	Within groups	143.15	77	1.859		
	Total	417.407	83			

Dependent Variable: SEN	B	Std. Error	T	Sig.
(Constant)	14.682	0.374	39.305	0.000
Weekly Training in LA and NSL	-0.819	0.084	-9.801	0.000

Table 4.2.8b shows the simple linear regression analysis on the sustained effect of low-altitude and near-sea-level training on speed endurance of male amateur endurance runners of Bauchi State, Nigeria. The results revealed that low-altitude training and near sea level caused significant improvement in speed endurance of male amateur endurance runners of Bauchi State, Nigeria (F = 324.587, R = .735[a], R^2=0.539 and Adjusted R square = -0.534). The findings further revealed that the effect of low-altitude training on speed endurance was sustained at near-sea-level within three weeks among male amateur endurance runners (P = 0.000).

To determine the phases of training that was responsible for the significant effect, post-hoc least square difference (LSD) test for multiple comparison was applied on the data at baseline, 1st, 2nd and 3rd weeks of training at low-altitude and near sea level was analyzed and the results is presented in table 4.2.8c

Table 4.2.8c Results of LSD *post-hoc* tests on SEN of amateur distance runners for Low-altitude and Near Sea Level

(I) Duration	(J) Duration	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Baseline	Week 1	3.253*	.200	.000	2.814	3.693
	Week 2	2.713*	.670	.002	1.239	4.187
	Week 3	3.287*	.360	.000	2.494	4.079
Week 1	Baseline	-3.253*	.200	.000	-3.693	-2.814
	Week 2	-.540	.677	.442	-2.031	.951
	Week 3	.033	.371	.930	-.783	.850
Week 2	Baseline	-2.713*	.670	.002	-4.187	-1.239
	Week 1	.540	.677	.442	-.951	2.031
	Week 3	.573	.581	.345	-.705	1.852
Week 3	Baseline	-3.287*	.360	.000	-4.079	-2.494
	Week 1	-.033	.371	.930	-.850	.783
	Week 2	-.573	.581	.345	-1.852	.705
(I) Duration	**(J) Duration**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval for Difference**	
					Lower Bound	**Upper Bound**
Baseline	Week 1	.176	.370	.644	-.639	.991
	Week 2	2.373*	.267	.000	1.785	2.962
	Week 3	2.500*	.408	.000	1.601	3.399
Week 1	Baseline	-.176	.370	.644	-.991	.639
	Week 2	2.198*	.390	.000	1.339	3.056
	Week 3	2.324*	.362	.000	1.528	3.120
Week 2	Baseline	-2.373*	.267	.000	-2.962	-1.785
	Week 1	-2.198*	.390	.000	-3.056	-1.339
	Week 3	.127	.285	.665	-.501	.754
Week 3	Baseline	-2.500*	.408	.000	-3.399	-1.601
	Week 1	-2.324*	.362	.000	-3.120	-1.528
	Week 2	-.127	.285	.665	-.754	.501

Table 4.2.8c showed that significant improvement in speed endurance was between baseline and week 1st, 2nd and 3rd week at low altitude. On return at near sea level, speed significantly improved after the 2nd and 3rd week of training.

Summary of the findings:

1. Low-altitude and near sea level training significantly reduced pulse rate (p = 0.000) of male amateur endurance runners of Bauchi State, Nigeria.

2. Only low -altitude training caused significant increase on haematocrit level (p = 0.000) but not at near-sea-level training ($p = 0.137$) of male amateur endurance runners of Bauchi State, Nigeria.
3. Low-altitude and near sea level training significantly reduced respiratory frequency ($p = 0.000$) of male amateur endurance runners of Bauchi State, Nigeria.
4. Low-altitude and near-sea-level training significantly improved VO_2max ($p = 0.000$) of male amateur endurance runners of Bauchi State, Nigeria.
5. Low-altitude training did not affect potassium level ($p = 0.064$) but caused significant effect on potassium level ($p = 0.000$) at near-sea-level of male amateur endurance runners of Bauchi State, Nigeria.
6. Both low-altitude ($p = 0.214$) and near sea level training ($p = 0.064$) did not cause significant effect on sodium level of male amateur endurance runners of Bauchi State, Nigeria.
7. Low-altitude and near sea level training significantly improved speed endurance ($p = 0.000$) of male amateur male endurance runners of Bauchi State, Nigeria.

4.3 Discussion

The purpose of this study was to assess the effects of low and near sea-level training on cardiopulmonary functions and electrolyte level of male amateur endurance runners of Bauchi State, Nigeria.

The findings of this study revealed that low-altitude and near-sea-level training significantly reduced pulse rate of male amateur endurance runners of Bauchi State, Nigeria ($p = 0.000$). The result of this study is in agreement with Muza et al, (2004); Michelle and Luigi (2011), who had observed significant reduction in pulse rate of

endurance runner after low altitude exposur and return to sea level training. The sustained reduction in pulse rate on return to near sea level corroborated earlier findings of Bakdima (2016); Bakdima, Dargak and Gunen (2019), who have reported sustained lower heart rate of endurance runners after moderate altitude exposure. The reduction in pulse rate of this study implies an increase in haematocrit, stroke volume and cardiac output which are factors that enhance athletes' aerobic capacity for better performance. This reduction in pulse rate could also be as a result of increased and continuous adaptation to training work load, improved mitochondrial density and re-acclimatization at near sea level (McArdle et al, 2010).

The findings of this study revealed that haematocrit level increased significantly ($p = 0.000$) at low altitude stay. This result is in line with Cedera (2002), Wilmore and Costill (2004) and Levine *et al,* (2005), who reported that even few days of low-altitude exposure, would cause erythropoietin from the kidneys to stimulate red blood cells (RBC) production and eventually leads to higher haemoglobin and haematocrit levels. The increase in haematocrit of this study supported the observation of Saunders *et al*, (2013); who reported that upon ascending to low-altitude, the reduced fraction of inspired oxygen (FiO_2) induces erythropoietin (EPO) production, which in turn stimulates the production of RBCs, increasing haemoglobin mass and haematocrit. Furthermore, Rusko, Tikkanen and Peltonen, (2004); Chapman and Sinex, (2015) who, stressed that in response to relative lack of adequate oxygen for delivery of nutrients to exercising tissues, the body increases the production of red blood cells mass, haemoglobin and haematocrit to meet up oxygen demands. The results of other researchers supported the fact that on exposure to low altitude, erythropoietin normally stimulates red blood cell production and eventually leads to higher haemoglobin and haematocrit levels (Brook & Fahey, 2010; Elaine & Katja,2012). Therefore, the body under this state of hypoxia will respond in time by

increasing the formed elements (haematocrit) or RBCs in the blood stream to compensate for lower oxygen levels. The result of this study clearly indicated that the duration of stay was sufficient to achieve the primary target of training at low altitude, which is to increase the total volume of haematocrit, red blood cells there by increasing the oxygen carrying capacity of arterial blood, which results to greater endurance performance (Levine *et al*, 2005).

Though haematocrit level did not increase during the training period at near sea level. It is however observed that the increased haematocrit level at low altitude could only be sustained for about 16 days on return to near sea level. This support the position of coaches and sport scientist who have reported consistently that haematocrit level can return to baseline level within few days of return to sea level after altitude exposure of elite endurance runners (Rice *et al;* 2005; Risso, Geiser & Coste, 2007). Furthermore, Chapman, Levine and Ventura (2010), reported that an athlete's red blood cell count (haematocrit) returns to initial levels within days of return to sea level. The result of the present study which showed that the haematocrit level did not return to pre low altitude training level upon return to near sea level could be attributed to the fact that the near sea level was used (628m above sea level) instead of sea level as reported in most literature. This suggest that any level above sea level have an impact on the result. This is also supported by Levine *et al*, 2005 who maintained that the level of altitude and duration of training play a role in haematocrit and red blood cells level.

The results revealed that low-altitude and near-sea-level training influenced respiratory frequency of male amateur endurance runners of Bauchi State, Nigeria ($p = 0.000$) The findings further revealed that the effect of low-altitude training on respiratory frequency was sustained at near-sea-level within three weeks among male amateur endurance runners ($p = 0.000$). The baseline result of this study supports the findings of

Faramoushi, *et al*, (2012), who reported that low tissue oxygen content at low-altitude causes immediate increase in respiration. Also, Wilmore & Costill (2004) and Savard (2011), reported that pulmonary ventilation (breathing) increased at altitude both at rest and during exercise as a result of oxygen molecules in a given volume of air is less at low altitude. Therefore, more air must be inspired to supply as much oxygen as during normal breathing at sea level. The increase in ventilation is to bring in a larger volume of air to meet up demand impose by altitude exposure. The result of this study supported Hamlin *et al*, (2013), who observed and reported that respiratory rate changes and reduces with exercise of different intensity at low-altitude after exposure to three weeks training duration. The mechanisms for this reduction could be increased alveoli in the lungs, increased haematocrit and tissues adaption to training loads. On return to near sea level there was reduction in RF through the third week of training. These results are in line with the findings of Molinero, (2013), who reported that respiratory rate is sustained for many days at sea level after low altitude exposure.

The results of this study further revealed that exposure to low-altitude and near-sea-level training improved VO_2 max of male amateur endurance runners of Bauchi State, Nigeria ($F = 9.222$, $R = .644^a$, $R^2=0.415$ and Adjusted R square = 0.408). The findings further revealed that the effect of low-altitude training on VO_2max was sustained at near-sea-level within three weeks among male amateur endurance runners ($P = 0.000$). The result of this study on VO_2max. is in line with the findings of Brook and Fahey (2010), who reported that oxygen uptake improved with prolonged exposure to low-altitude training. The result of the study further confirmed the findings of Porcari, Probst, Forrester, Doberstein, Foster, Cress and Schmidt (2016); Bakdima, Gunen and Dargak (2019), who reported significant improvement in VO_2max after exposing endurance athletes to moderate and low-altitude training. The result of this study on $V0_2$max is in agreement

with IAAF (1994) findings which showed that after training at low-altitudes of between 1250 m and 2800 m, above sea level, there was an increase in oxygen uptake of 12.5% on the 13th day after return to sea level. Allan, Hahn and Gore (2001) stressed that one of the mechanisms for an enhanced endurance performance is an increase in the capacity to transport oxygen to the muscles which near sea level re acclimatization training is capable of stimulating. In support of this study Park, Hwang, Park, Lee, and Lim (2016) stated that low-altitude training is constantly used for enhancing maximal oxygen consumption (VO2max), and exercise performance at sea level.

The result revealed that low-altitude and near-sea-level training had no effect on potassium level of male amateur endurance runners of Bauchi State, Nigeria (F = 6.522, R = .073^{a}, R^2=0.005 and Adjusted R square = -0.007). The findings further revealed that the effect of low-altitude training on potassium level was not sustained at near-sea-level among male amateur endurance runners (P = 0.507). These findings support the result of the study of Lara, Gallo-Salazar, Puente, Areces, José Salinero and Del Coso, (2016), who found that there was no significant correlation between potassium concentration and running pace of marathon runners at altitude. This means that the participants did not suffer dehydration. Upon return to near sea level an improvement was observed in the potassium balance of the participants. This finding is in contrast with the study of Rhoda, Porter, and Quinitini, (2011); Schmidt 2010 who reported that Potassium is integral to maintaining the body's fluid balance for better endurance performance.

The results revealed that low-altitude and near-sea-level training had no influence on sodium level of male amateur endurance runners of Bauchi State, Nigeria (F = 3.491, R = .0157^{a}, R^2=0.025 and Adjusted R square = -0.013). The findings further revealed that the effect of low-altitude and near-sea-level training did not influenced sodium level of male amateur endurance runners (P = 0.153). The result of this study was in contrast with Lara,

Gallo-Salazar, Puente, Areces, José Salinero and Del Coso, (2016) who reported that there was significant correlation between sodium concentration and running pace of marathon runners. (r = 0.18; P = 0.03). Furthermore, Fulco,1988 and Barker, (2018) stated that an imbalance of sodium at altitude can lead to serious disruptions in physiologic function thereby affecting performance. At near sea level steady reduction was observed in the sodium balance of the participants. The result of this study was in agreement with Barker (2018) who stated that an imbalance of any electrolytes can lead to serious disruptions in physiological functions particular among endurance athletes who trained for hours daily

The results of this study also revealed that low-altitude and near-sea-level training led to significant improvement in speed endurance of male amateur endurance runners of Bauchi State, Nigeria (F = 324.587, R = .735[a], R^2=0.539 and Adjusted R square = -0.534). The findings further revealed that the effect of low-altitude training on speed endurance was sustained at near-sea-level within three weeks among male amateur endurance runners (*P* = 0.000). The result of this study confirmed the findings of Terrados (1992) who observed measurable increase in maximum aerobic power among endurance athletes detectable even with training at an altitude 900 m. This supports experiences of sea level middle- and long-distance runners who noticed performance improvement when they trained and performed at altitudes as low as 700 m to 800 m. Beneficial physiological adaptations have been observed from runners' experiences at altitude. Training at altitude of over 1000 m provides an additional hypoxic stress similar to the changes seen with hard training at sea level. In support of the study Miller (2014) stated that the higher the altitude the more athletic performance drops off due to the climatic changes, which consequently affects performance. In support of this study Mortan and Cable (2015) found out that speed endurance performance drops in athletes immediately on ascent to altitude, and improved with acclimatization. The improvement in speed endurance observed in this

study could be attributed to the athlete's ability to acclimatize fast. Elaine and Katja (2012) have stressed that under the condition of hypoxia the body responds in time by increasing haematocrit to compensate for lower oxygen level, which strives to produce the required amount of energy to meet oxygen and nutritional needs of exercising muscles. Supporting this position, Allan, Hahn and Gore (2001) maintained that the mechanisms of enhancement of speed endurance performance is probably an increase in the capacity to transport oxygen to the muscles as well as the capacity to buffer lactic acid which altitude training is capable to stimulating. At near-sea-level there was steady improvement in speed endurance performances of the participants in this study. This support the fact with re-acclimatization to near-sea-level, improvement in speed endurance peaked after the 14^{th} to 18^{th} day after low altitude exposure.. This result is in line with the findings of Muza *et al.* (2004), who reported that with continues and correct training loads athletes' potentials for speed endurance improvement is enhanced. The result of the study was in line with Mazzeo (2008); Morton and Cable (2015) who found out that 3-week duration stay and training at low-altitude could be beneficial to speed endurance athlete's performance after 12-14 days of return to sea level.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

This study was conducted to assess the influence of low-altitude and near sea level training on cardiopulmonary functions and electrolyte balance of male amateur endurance runners of Bauchi state, Nigeria. The following variables assessed included pulse rate, haematocrit, respiratory frequency, VO_2max, potassium and sodium levels as well as speed endurance of the participants. Elevations of 1414m above sea level, located in Pankshin, Plateau State and 628 m above sea level in Bauchi, Bauchi State for duration of three (3) each respectively were used as low-altitude and near sea level centres for this study. One (1) major hypothesis and seven (7) sub-hypotheses were formulated for the study. Related literature was reviewed on altitude and altitude training. Physiological responses and adaptations to low altitude training were assessed including the pulse rate, haematocrit, VO_2max, respiratory frequency, potassium and sodium levels and speed endurance responses. Repeated measures experimental research design was used for this study and twelve (12) participants whose ages were between 20 and 30 years old, who met the inclusion criteria for participation in the training programme were used for this study. The participants were assessed at baseline, immediately after the end of 1^{st}, 2^{nd}, and $3^{rd,}$ week each at low-altitude and near sea level respectively.. Haematocrit, sodium and potassium

were assessed in the laboratory by analyzing the blood serum samples of the participants, pulse rate was assessed by using the automated digital blood pressure monitor, respiratory frequency was measured by the use of a spirometer to determine the number of inhalation and exhalation cycles of the runners per minute in percentage, VO_2max. of the runners was assessed using the 12 minute run/walk test, while speed endurance was determined by performances in 3,000 m distance time trails.

All training sessions were conducted in the morning between 7:00 – 8: 30 am and in the evening between 4:30 – 6:00 pm from Monday to Saturday for duration of three weeks each at low-altitude and near sea level. The training schedule comprised of ten (10) minutes general warm up, which included: slow pace jogging and stretching activities to prepare the athletes for the main activity. Warm down activity of 10 minutes consisting of slow jogging, stretches and massages where necessary after each training session. The training programmes ranges from interval and continuous training, road works, including hill training were conducted

The data collected were statistically analyzed using descriptive statistics, repeated measures analysis of variance and linear regression analysis. All statistical analyses were carried out using Statistical Package for Social Sciences (SPSS) package. The hypotheses were tested at 0.05 alpha-level of significance.

5.1.2 Findings

1. Low-altitude and near sea level training significantly reduced pulse rate (p = 0.000) of male amateur endurance runners of Bauchi State, Nigeria.
2. Only low -altitude training caused significant increase on haematocrit level (*p* = 0.000) but not at near-sea-level training (*p = 0.137*) of male amateur endurance runners of Bauchi State, Nigeria.

3. Low-altitude and near sea level training significantly reduced respiratory frequency (*p = 0.000*) of male amateur endurance runners of Bauchi State, Nigeria.
4. Low-altitude and near-sea-level training significantly improved VO_2max (*p = 0.000*) of male amateur endurance runners of Bauchi State, Nigeria.
5. Low-altitude training did not affect potassium level (*p = 0.064*) but caused significant effect on potassium level (*p = 0.000)* at near-sea-level of male amateur endurance runners of Bauchi State, Nigeria.
6. Both low-altitude (*p = 0.214)* and near sea level training (*p = 0.064)* did not cause significant effect on sodium level of male amateur endurance runners of Bauchi State, Nigeria.
7. Low-altitude and near sea level training significantly improved speed endurance (*p = 0.000*) of male amateur male endurance runners of Bauchi State, Nigeria.

5.1.3 Contribution to knowledge

The following contributions were made from this study:

1. Low-altitude training caused significant reduction in the pulse rate (*p* = 0.000) and was sustained at near sea level among male amateur endurance runners of Bauchi State, Nigeria.
2. low-altitude and near-sea-level training significantly improved and sustained haematocrit level (p = 0.001) of male amateur endurance runners of Bauchi State, Nigeria.
3. Low-altitude and near sea level training significantly improved and sustained respiratory frequency (p = 0.001) of male amateur endurance runners of Bauchi State, Nigeria.

4. Low-altitude and near-sea-level training significantly improved and sustained VO_2max (p = 0.001) of male amateur male endurance runners of Bauchi State, Nigeria.
5. Low-altitude training and near-sea-level training did not significantly affect potassium level (p = 0.507) of amateur male endurance runners of Bauchi State, Nigeria.
6. Low-altitude training did not affect sodium balance (p = 0.153) as did (p = 0.000) near sea level training of male amateur endurance runners of Bauchi State, Nigeria.
7. Low-altitude and near sea level training significantly improved and sustained speed endurance (p = 0.000) of male amateur endurance runners of Bauchi State, Nigeria.

5.2 Conclusion

On the basis of the result and in view of the limitation of the study the following conclusion were drawn:

1. Low-altitude and near sea level training significantly reduced pulse rate of male amateur endurance runners of Bauchi, Nigeria
2. Low-altitude and near-sea-level training significantly improved haematocrit production rate of amateur male endurance runners of Bauchi, Nigeria.
3. Low-altitude and near sea level training significantly reduced the respiratory frequency of male amateur endurance runners of Bauchi, Nigeria.
4. Low altitude and near sea level training significantly improved (P = 0.000) VO_2 max of amateur male endurance runners of Bauchi, Nigeria.
5. Low-altitude and near-sea-level training did not caused significant change in the potassium level of male amateur endurance runners of Bauchi, Nigeria.

6. Low-altitude training did not changed sodium balance however there was a significant improvement at near-sea-level among male amateur endurance runners of Bauchi, Nigeria.

7. Low-altitude and near sea level training significantly improved speed endurance of male amateur endurance runners of Bauchi State, Nigeria.

5.3 Recommendations

Based on the results of this study, the following recommendations are made:

1. Exposure to low-altitude training and near sea level training were shown to improve indices pf endurance events performances. Therefore, endurance runners and coaches in Bauchi state should incorporate altitude training as part of the training programmes in preparing endurance athlete for national and international competitions.

2. Exercise scientists, coaches and sports professionals should use the results of this study as a research block towards improving endurance events performances among athletes in Nigeria.

3. Participants of this study should be further exposed to altitude and other endurance related training programmes periodically by Bauchi State Sports Council to further equipped them for better performance at national and international competitions.

4. Coaches should also be exposed to seminars, conferences and refresher courses on endurance and altitude training programme planning by relevant sports organizations.

5. Male amateur endurance runners of Bauchi State Sports Council need to utilize low-altitude training camp of Pankshin to boost the energy reserve of their athletes. It is further recommended that endurance runners should be exposed to higher

altitude sea level training camps in Nigeria to assess their HCT%, $VO_{2max,}$ Speed endurance, respiratory frequency and Pulse rate.

5.4 Limitation of the Study

Fifteen (15) male amateur endurance runners of Bauchi were recruited for the study, but three (3) dropped as a result of ill-health, these participants were managed by health personnel at the General Hospital Pankshin. However, they could not cope with the environmental challenges and were returned home at the second week of stay at low-altitude. Only twelve participants met the required attendance. Therefore, only twelve (12) participants were considered in interpreting the results of the study.

5.5 Suggestions for Further Research

In the course of this study, the researcher wishes to make these suggestions for further research:

1. A similar study could be undertaken on female endurance runners in Nigeria for consideration of gender equality as this study was only conducted on male athletes.
2. Haematocrit could slightly decreased towards the end of the third week at near sea level, it is therefore, recommended that further studies could be conducted to ascertain the precise period of this decline.
3. There is need for further studies on Sodium and potassium levels of male amateur endurance runner to ascertain their variability mechanisms or otherwise at low and moderate altitudes and sea level centres in Nigeria.
4. There is the need to monitor pulse rate, lactate and pulmonary indices on daily basis to establish their points of stability among endurance runners inNigeria

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Appendices

Appendix I

Department of Haman Kinetics and Health Education,
Faculty of Education
Ahmadu Bello University, Zaria.

Dear participant,

Informed Consent Form

I Mr., _____ hereby consent voluntarily to participate in the training, testing and evaluation of my cardiopulmonary and electrolyte variables. I also agree voluntarily to take part in 6 weeks altitude training programme as part of research programme titled 'Effects of low altitude and sea level re-acclimatization on cardiopulmonary function and electrolytes balance of male endurance runners of Bauchi, Nigeria'.

I understand that the risk of this program may include minor discomforts such as headache, pains, dizziness, nausea, rise in heart rate and fatigue. I can discontinue in any aspect of the training program without any prejudice toward me. I equally know that selection and supervision of the training program is a matter of professional judgment.

I further understand that the information from the training program may be used for report and research publication. However, I am aware that my identity will not be disclosed.

Haven read the above statements; I will therefore perform these activities on my volition.

Name of participant _____ Date _____

Name of witness _____ Date _____

Name of researcher _____ Date _____

Appendix II

Introductory Letter for Collection of Data

DEPARTMENT OF HUMAN KINETICS AND HEALTH EDUCATION

AHMADU BELLO UNIVERSITY, ZARIA - NIGERIA

OFFICE OF THE HEAD OF DEPARTMENT

VICE CHANCELLOR Professor Ibrahim Garba B.Sc, M.Sc., (ABU); Ph.D. (London); D.I.C.

HEAD OF DEPARTMENT: Professor M. A. Suleimar , N.C.E. (OYSCE), B.Sc. (UNICAL); M.Sc, Ph.D. (ABU)

Our Ref. No. P17EDPE9013 Date: ----------

Dear Sir/Madam,

INTRODUCTORY LETTER FOR COLLECTIC N OF DATA: MAIYANGA BULUS YUYU (P17EDPE9013)

The bearer is a postgraduate student of the above na ned Department and University. He is conducting a research on the **"Effects of Low Altitu de Training and Near-Sea Level Re-Acclimatization on Cardiopulmoriary Function and Electrolytes Balance of Male Amateur Endurance Runners in Bauchi,, Nigeria".**

In this regards, I wish to request for your kind perı ission and co-operation to allow him use some of the athletes and sport facilities of your Ir stitution/Gym for data collection.

Your assistance to him will be highly appreciated.

Yours faithfully,

Prof,. E. A. Gunen
Major Supervisor