IOSR Journal of Sports and Physical Education (IOSR-JSPE)
e-ISSN: 2347-6737, p-ISSN: 2347-6745, Volume 5, Issue 6, (Nov. –Dec. 2018), PP 43-48
www.iosrjournals.org

Effects of Moderate Altitude Training on Cardiorespiratory Endurance (VO_2 max,) of Male Amateur Distance Runners in Plateau State, Nigeria

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Abstract: *The study was designed to find out the effects of 3 weeks moderate altitude training on cardiorespiratory endurance (VO_2 max) of male amateur distance runners of plateau state, Nigeria. Pankshin which is located at an altitude of 1414 m was used as the venue of the study. A 1x4x1 factorial research design was used for the study. The 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_2 max.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_2 max 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_2 max. ($P = 0.000$) 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.*

Date of Submission: 23-01-2019 Date of acceptance: 07-02-2019

I. Introduction

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[1]. [2] supported this by stating that, on arrival at an elevation of 2,300 m and above, initiation of rapid physiological adjustments occur 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. [3] observed the following physiological responses of athletes exercising at high and low pressure environments:

a. Ventilation: 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. This increase in ventilation if persistent reduces the amount of alveolar and blood carbon dioxide leading to respiratory alkalosis. The kidneys compensate by excreting more bicarbonate ion, decreasing the blood's buffering capacity and reducing the alkalosis (compensated respiratory alkalosis)
b. Pulmonary oxygen diffusion: Oxygen diffusion across the alveolar capillary membrane is dependent upon alveolar partial pressure of oxygen. This decrease as altitude increases leads to a decrease in oxyhaemoglobin saturation. At sea level haemoglobin is 98% saturated, but this falls to 92% at 2400 m altitude.

c. Muscle oxygen gas exchange: The pressure gradient between blood and muscle oxygen concentration is 74 mm Hg at sea level. This gradient is the major factor responsible for muscle oxygen gas exchanges during tissue oxygenation. 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: Plasma volume decrease soon after altitude exposure and level off after a few weeks. This leads to an increased red blood cell concentrations. Plasma volume is gradually restored and erythropoietin from the kidneys stimulates RBC production; thus, increasing haematocrit rate than at sea level.
e. Cardiac output: Cardiac output increases at altitude to compensate for the reduced partial pressure of oxygen and decreased oxygen delivery to tissues. Initially, this is accomplished by an increase in heart rate, as stroke volume is lower due to the increased plasma volume. After a few days, tissue oxygen extraction improves (increased A-VO_2 difference) and this reduces the cardiac demands. At maximal work-loads, maximal stroke volume, heart rate and tissue oxygen diffusion are reduced, thus, total maximum VO_2 max and aerobic work are diminished.
f. Metabolic adaptation: As oxidative pathways are limited at altitude, there is a shift towards anaerobic energy sources. At any given work level, lactic acid production is higher than at sea level. However at maximal workloads lactic acid is lower possibly because work levels are too low to maximally activate all energy systems.
g. Maximal oxygen uptake/consumption: Maximal oxygen uptake measures the ability of the body to take in, transport, and utilize oxygen. It decreases as altitude increases, but does not begin to fall until atmospheric partial pressure of oxygen drops below 125 mm Hg. 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_2 max decreases by 11% for each 1,000m above the 1,600m level. [4]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.

[5]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. [6]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 has to develop some adaptations and changes that allows the oxygen transport system to compensate for the hypoxia in order to maintain an adequate tissue oxygen level to support metabolism.

[7] 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 runner's 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 [8]. [9] 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. It is in view of the challenge of oxygen deficit and possible adaptation at moderate altitude which could lead to performance enhancement that motivated the authors of this work to write on the topic.

Plateau State is located in the North Central part of Nigeria with a favourable weather condition having means annual ambient temperature values of between 21^{o}C and 27^{o}C. It is classified as one of the coolest areas in the country, characterized by cool and favourable weather conditions, particularly in the Northern and Central Senatorial zones, with mean annual ambient temperature values of between 20^{o}C and 25^{o}C in Jos and Pankshin, while the Southern Senatorial zone has a warm and hot climatic weather with mean annual ambient temperature value of over 27^{o}C in Shendam, similar to the weather conditions of Niger and Benue lowlands. Furthermore, the Northern and Central Senatorial zones of the State have elevations of between 1,280 m and 2,650 m above sea level as found in Kuru, Naraguta, Pankshin and Shere Hills, while the Southern zone has 289 m above sea level in Shendam[10]. Therefore, Pankshin which is found within the central senatorial zone with an elevation of 1414 m above sea level and considered a moderate altitude environment was used as the venue for the study.

Hypothesis

There is no significant effect of moderate altitude training on VO_2 max, of male amateur distance runners of Plateau state, Nigeria.

II. Methodology

Research Design: 1x4x1 factorial research design was used for this study.In this design moderate altitude environment was used for the study, four levels of assessment were conducted at baseline, at the end of first, second and third weeks of training on one variable.

Population: The population for this study consist of male amateur distance runners of plateau state, Nigeria.

Sample: A purposeful sampling technique was adopted to select fifteen (15) out of 19 amateur distance runners based on their closed VO_2 max, who were dwellers of low altitude environment (Shendam) from the southern senatorial part of the state after a 12minutes run test. This was to determine the effect of moderate altitude exposure on the runners.

Instrumentation: The following instrument were used for the study;

- ❖ A standard 400m track
- ❖ Hilltop road Pankshin (650 m)
- ❖ Whistle
- ❖ An electronic stop watch

Training Protocols and Programme: The training programme that was used was the interval training, which consisted of running and other resistance activities. Daily training programme was executed in the mornings and evenings for a period of three weeks at moderate altitude. Before the execution of any training schedule, 10 minutes was used for general warm-up exercises, which composed mainly of stretching activities to prepare the athletes. An example of training schedule, which is shown on the Table of the training programme below for the entire training period is the 4 x 2 x 400 m) 65" (3'/5') adopted [11]: The interpretation of this programme implies that two repetitions of 400 m running at an intensity (space) of 65 Sec. with a recovery period of 3 minutes with 5 minutes rest between 4 sets. The schedules of the programme were alternated between heavy and light rhythms of training as suggested [12] and [13] to allow time for recovery and better output.
The training venue was in Pankshin, which has an altitude of 1414 m above sea level and was considered a moderate altitude environment [10, 14].

Table no 1: Schedule of the training programme

Week1/Days	**Morning (am)**	**Evening (pm)**	**Intensity**
Monday	5-8km slow pace run	5 x 1200 m) 2' (5')	60% individual effort
Tuesday	Hill training of (200 m x 5) at 35"(40")	4 x 2 x 400 m) 65" (3'/5')	65% individual effort
Wednesday	6-10km road work at 70% $V0_2$max. (35')	6x200m) 36" (2')	60% individual effort
Thursday	weight training 30kg 8-12 repetition 4-6 sets	20-30 minutes diagonal run on a football pitch	70% individual effort
Friday	2 x 3 x 300 m (400 m pace) 40"(3'/5')	3 x 6 x 150 m) 20" (1'/3')	60% individual effort
Saturday	Trials and assessment		80% individual effort
Week 2/Days	**Morning (am)**	**Evening (pm)**	**Intensity**
Monday	8km fast road work at 65% $V0_2$max.	3x3x450 m)70"(2'/5')	70% individual effort
Tuesday	2 x 5 x 500) (5000 m pace) 1½'/4'	2x3x300 m (300 m pace) 40" (2'/5')	65% individual effort
Wednesday	12km steady run marathon pace (40')	2x2x1000 m) 5000 m pace (1½'/5')	70% individual effort
Thursday	40-50mins. Continues run at 60% $V0_2$max.	3x4x200 m) 30" (3'/4')	65% individual effort
Friday	12 km long road work (40')	stretching exercises 150 m x 8 (20")	65% individual effort
Saturday	Trials and assessment		80% individual effort.
Week3/Days	**Morning (am)**	**Evening (pm)**	**Intensity**
week 3/Days			
Monday	8 km fast road work	3x3x500 m (<3000 m pace)(45'and 5')	75% individual effort
Tuesday	Hill training 120 m x 5/25"	2x4x200 m at 90% $V0_2$max. (30" and	65% individual effort

		4')	
Wednesday	3x5x400 m) 70-75" (4')	100 m curve and straight run 10 each (10x4 = 40 times)	75% individual effort
Thursday	2x6x150 m) 24" (1'/3')	30-50 minutes continues run on grass	75% individual effort
Friday	8x300 m) 36" (40")	stretching exercises 10 x 100 m) 15"	70% individual effort
Saturday	Trials and assessment		80% individual effort

Source: [11]

Procedure for Data Collection: The 12-minute run-field test was conducted to measure cardiorespiratory endurance (VO_2max.) in m1.kg.min^{-1} of the participants[15] and [16]stated that the average untrained healthy male and female should have a VO_2 max. of approximately 35-40 ml. kg.min^{-1} and 27-31 ml.kg.min^{-1} respectively. These scores have been shown to improve with training and decrease with age.
The ACSM formula for the calculation of $V0_2$ max as suggested by Cooper (1968) in [13] is 35.97 -11.29, where d_{12} is distance in miles covered in 12 minutes. For instance, if an athlete covers six laps, which is 400 m x 6 = 2400 m.
This distance in metres was converted to miles which was worked as follows:
2400 m / 1609.334 m which is the distance of 1 mile = 1.491.609 miles
Therefore, 35.97 (1.491.609) -11.29
VO_2max. = 42.363 ml. kg.min^{-1}.
This measurement was taken before the commencement of training (base-line), at the end of trainings in weeks one (1), two (2) and three (3), between 7:00 am and 8:30 am.

III. Result

The physical characteristics of participants at base-line, immediately after the first, second and third week of training are presented below;

Table no 2: Mean, Standard deviation and standard error of estimate of the age, weight (kg), height (m) and body mass index (kg/m^2) of the participants at base-line, immediately after the first, Second and third week of training at moderate altitude:

Moderate Altitude

Duration	Variable	Mean	SD	SE
Baseline	Age (year) Weight (kg) Height (m) BMI (kg/m^2)	18.866 55.866 1.636 20.771	1.959 8.245 .03043 2.835	.506 2.128 .0076 .732
1st week	Weight (kg) BMI (kg/m^2)	55.066 20.300	8.030 2.619	2.073 .676
2nd week	Weight (kg) BMI (kg/m^2)	54.066 20.066	7.869 2.605	2.031 .672
3rd week	Weight (kg) BMI (kg/m^2)	52.933 19.644	7.439 2.426	1.920 .626

Male distance runners used for this study were 18.87±1.96 years old with mean body weight of 55.87 ± 8.25 kg; 1.64 ± 030.43m in height and BMI of 20.77 ± 2.84 kg/m^2. As training progressed the mean weight and BMI decreased after the first week to 55.066 ± 8.030 kg and 20.300 ± 2.619 kg/m^2 respectively. Further decrease was observed in the 2nd week with a weight mean and BMI of 54.066 ± 7.869 kg and 20.066± 2.605 kg/m^2 respectively. At the end of the third week of training, marked decrease was noticed in the mean weight (52.933 ± 7.439 kg) and BMI (19.644 ± 2.426 kg/m^2).

Table no 3: Descriptive statistics of mean, standard deviation and standard error mean of VO_2 max of participants at moderate altitude

Variable	Moderate Altitude				
	Duration	**N**	**Mean**	**SD**	**SEM**
VO_2 max **(ml.kg.min^{-1})**	Baseline Week 1 Week 2 Week 3 Average	15 15 15 15	53.474 58.479 59.117 59.811 57.721	6.593 5.321 5.938 6.086 6.366	1.702 1.374 1.533 1.571 .821

The table no 3 shows the means, standard deviation and standard error of mean of $V0_2$ max of amateur distance runners on arrival (baseline), immediately after the 1st, 2nd and 3rd week of training at moderate altitude. An observation of the table revealed that the participants had means $V0_2$ max of 53.47±6.59, 58.48±5.32; 59.12±5.94 and 59.81±6.09ml.kg.min^{-1} at baseline, immediately after the 1st, 2nd and 3rd week of training at moderate altitude respectively. It is observed that the VO_2 max almost reached its plateau at the 2nd and 3rd week of stay at moderate altitude.

To establish whether this improvement in $V0_2$ max data was statistically significant, the data was analyzed using repeated measures analysis of variance (ANOVA), the result of which is presented below;

Table no 4: Repeated-measures analysis of variance (ANOVA) on VO_2 max of amateur distance runners at moderate altitude.

		SOURCE	SS	DF	MS	F	Sig.
	Time	Sphericity assumed	373.808	3	124.603	31.703	.000
		Green house-Geisser	373.808	1.485	251.702	31.703	.000
		Huynh-Feldt	373.808	1.620	230.714	31.703	.000
		lower bound	373.808	1.000	373.808	31.703	.000
	Error (Time)	Sphericity assumed	165.075	42	3.930		
		Green house-Geisser	165.075	20.792	7.939		
		Huynh-Feldt	165.075	22.683	7.277		
		lower bound	165.075	14.000	11.791		

The table no 4 shows repeated measures analysis of variance (ANOVA) on the VO_2 max. of amateur distance runners at moderate altitude of Pankshin in Plateau State, Nigeria. Observation of the analysis revealed that training caused significant improvement on the VO_2 max of the participants as shown in the sphericity assumed. Further observation of the table confirmed a significant values of P, which are less than 0.05 (p =0.000). Therefore, the null hypothesis which states that there is no significant effect of moderate altitude training on VO_2 max of amateur distance runners of Plateau state, Nigeria is hereby rejected.

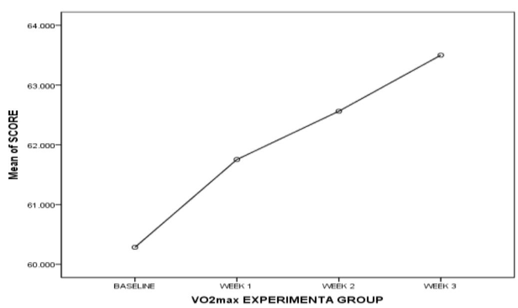
To establish which phase of training was responsible for the significant effect, *post-hoc* least square difference (LSD) tests for multiple comparison was applied on the means at baseline, 1st, 2nd and 3rd week at moderate and low altitude, the result of which is presented below:

Table no 5: Results of post-hoc LSD tests on VO_2 max of amateur distance runners at Moderate altitude

Moderate Altitude	Mean difference	SE	Sig.	95% confidence interval	
				lower bound	Upper bound
Baseline					
Week 1	-5.004*	2.191	.026	-9.394	-.613
Week 2	-5.641*	2.191	.013	-10.032	-1.251
Week 3	-6.336*	2.191	.005	-10.726	-1.945
Week 1					
Baseline	5.004	2.191	.026	.613	9.394
Week 2	-.637	2.191	.772	-5.027	3.753
Week 3	-1.331	2.191	.546	-5.722	3.058
Week 2					
Baseline	5.641	2.191	.013	1.251	10.032
Week 1	.637	2.191	.772	-3.753	5.027
Week 3	-.694	2.191	.753	-5.084	3.696
Week 3					
Baseline	6.336	2.191	.005	1.945	10.726
Week 1	1.331	2.191	.546	-3.058	5.722
Week 2	.694	2.191	.753	-3.696	5.084

Significant at 1st, 2nd and 3rd weeks

Table no 5shows that the significant difference was revealed at 1st, 2nd and 3rd week of training with P values less than 0.05. Further illustration of the result is hereby shown in the Figure below:



Means VO_2 max of the participants at moderate altitude

IV. Discussion

The results of the study revealed improvement in $V0_2$ max. of male amateur distance runners of Plateau State, Nigeria from the Base-line through the period of stay at moderate altitude. $V0_2$ max. improved from the base-line values of 53.474 $ml.kg.min^{-1}$, 58.479 $ml.kg.min^{-1}$, 59.117 $ml.kg.min^{-1}$ and 59.811 $ml.kg.min^{-1}$ after the first, Second and third week of stay respectively. This improvement was found to be statistically significant (P=0.000). The result on VO_2 max.[4]reported that oxygen uptake could be improved upon with prolonged exposure to altitude training. [18] also agreed with this finding by remarking that the mechanism of enhancement of endurance performance is probably an increase in capacity to transport oxygen to the muscles which altitude training is capable of stimulating. The study is also in agreement with [19] findings which revealed that after a training at altitudes between1250 m and 2800 m above sea level, there was an increase in oxygen uptake of 12.5% on the 13^{th} day after return to sea level. The mechanisms for this improvement might be attributable to the increase in the respiratory frequency, which was also obtained in addition to continued training load.

V. Conclusion

Based on the findings of this study, it is concluded that moderate altitude training significantly increased (p = 0.000) the VO_2 max, of male amateur distance runners of Plateau state, Nigeria from base-line values of 53.47 ml $kg.min^{-1}$, 58.48 ml $kg.min^{-1}$, 59. 12 $ml.kg.min^{-1}$ and 59.81 $ml.kg.min^{-1}$ at base-line, immediately after the first, second and third week of training.

VI. Recommendation

It is recommended that altitude training should be explored and encouraged by coaches and relevant agencies for performance enhancement among endurance athletes.

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J. N. Bakdima. "Effects of Moderate Altitude Training on Cardiorespiratory Endurance (VO2 max,) of Male Amateur Distance Runners in Plateau State, Nigeria." IOSR Journal of Sports and Physical Education (IOSR-JSPE) 5.6 (2018): 43-48.