

A COMPARATIVE STUDY ON
THE EFFECT OF ALTITUDE ON PHYSICAL PERFORMANCE

By 680

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TABLE OF CONTENTS

	PAGE
INTRODUCTION	1
PURPOSE	1
METHOD OF STUDY	2
LIMITATION OF STUDY	2
DEFINITION OF TERMS	3
ANALYSIS AND DISCUSSION	5
SUMMARY AND CONCLUSION	21
SELECTED BIBLIOGRAPHY	22

TABLES

PAGE

Table I	Athletes participating in the test on Ergometer studies . .	7
Table II	Results of Ergometer studies	8
Table III	Physical characteristics of athletes	16
Table IV	Running times for track events at 300 meters and 3,100 meters altitude	17

INTRODUCTION

Due to the fact that the 1968 Olympics were held in Mexico City this past year, there has been a lot of controversy on whether the altitude of this city, 2,300 meters or 7,540 feet, would have a direct or indirect effect on the physical performance of the athletes from around the world.

The effects of altitude have even greater importance with the recent aerospace programs advancing as rapidly as they are toward the limits of outerspace. What effect will the high atmospheric pressure have on the body organisms at this altitude is a constant concern of the doctors of the aerospace program. Will this altitude affect the body so it cannot function properly; will it affect the heart, brain and other vital organs, or will it react normally to an atmospheric pressure?

Questions such as these have to be answered before any progress can be made in this field. These questions are not only important to athletes and doctors, but also are of great importance to the general public who like to visit the mountains for their own leisure time and activities.

Does altitude have an effect on the body or is it just a myth?

Purpose

The first purpose of this study was to summarize certain articles of the nation's authorities on the effects of altitude.

The second purpose was to point out the different authors' beliefs as to what extent altitude affected the body and its organisms.

The third purpose was to point out what the authorities say would be the best training procedure to prepare for altitude competition.

METHOD OF STUDY

In gathering data and material for this report, the author wrote and telephoned several authorities on this field of study and obtained vital information from their personal research. Visits were made to the New York Public Library of New York, and the Kansas City Library of Kansas City, Kansas, for added material. The major portion of the research was conducted at Farrell Library, Kansas State University, Manhattan, Kansas. The use of the Kansas State University track office library at Ahearn Fieldhouse also proved very beneficial in the writing of this report.

Upon gathering the needed material for this library study, the author collected and reviewed articles of renown authorities and combined their opinions into a comparative study of their beliefs.

LIMITATIONS OF STUDY

The author was limited in finding up-to-date and published material since the effects of the altitude is relatively new to the sports world. It was realized that other material was available in some respect to this subject, but the author did not feel this material pertinent to this study.

DEFINITION OF TERMS

Since this study has to do with certain physiological functions of the body certain terms need to be mentioned so as to help the reader understand the paper

Acclimatization. The process of adapting to a new temperature, climate, altitude, etc.

Parameter. An arbitrary constant each of whose values characterize a member of a system.

Hypoxia. A deficiency of oxygen reaching the tissues of the body.

Anoxia. Hypoxia especially of such severity as to result in permanent damage.

Alimentary tract. Tubular passage that extends from mouth to anus and functions in digestion and absorption of food and elimination of residual waste.

Bradycardia. A slow heart rate.

Catheter. A tube to permit injection or withdrawal of fluids or to keep passage open.

Oxygen debt. A cumulative oxygen deficit that develops during periods of intense body activity and must be made good when the body returns to rest.

Ergometer. An apparatus for measuring the work performed by a group of muscles.

Aerobic. Living, active, or occurring only in the presence of oxygen.

Cardio-vascular. Relating to, or involving, the heart and blood vessels.

pH. Method of stating hydrogen ion concentration of a solution.

P CO₂. Phosphous carbonate.

H CO₃. Hydrogen carbonate.

Lactate. A salt or ester of lactic acid.

Stroke Volume. The amount of blood pumped by the heart with each beat.

Systolic. Pressure at the lowest point during the pressure cycle.

Diastolic. Pressure at the highest point during the pressure cycle.

Hemoglobin. An iron-containing protein respiratory pigment occurring in red blood cells of vertebrates.

Pulmonary edema. Fluid leakage from the pulmonary capillaries into the pulmonary tissue and alveoli.

ANALYSIS AND DISCUSSION

Acclimatization to altitude has numerous effects on the different organs of the body, which in turn have a direct or indirect effect on the physical performance of the body.

In relation to the digestive system, the gastrointestinal tract plays an important part in the well being of the organism.

Dr. Kaarlo Hartiala stated that it would be necessary to subject both man and animal to a rather severe grade of hypoxia before the movements of the alimentary tract are significantly affected.¹ He mentioned, however, that the gastrointestinal secretory functions and the behavior of the gastric and pancreatic secretions were inhibited by hypoxia. He emphasized again that deviations from usual secretory patterns will hardly affect utilization of the food stuffs at the altitude of Mexico City as far as the hydrochloric acid and pepsin were concerned.²

In an experiment on dogs which were subjected to breathing an 8 per cent oxygen mixture and collecting the pancreatic juice directly from the cannulated ducts and stimulating the pancreas by a constant secretin-pancreoxymin infusion, Dr. Hartiala concluded that the external pancreatic secretion is suppressed by anoxic anoxia.³ At the level of 2,300 meters, the reduction could actually disturb the digestion.

¹Hartiala, Kaarlo. "Digestive Functions In Altitude Conditions," The Effect of Altitude on Physical Performance, (Chicago: The Athletic Institute, 1967), p. 15.

²Ibid., p. 15.

³Ibid., p. 16.

In trying to avoid this feeling of hypoxia, it was advised that the participant not eat heavy meals before retiring for the evening. Allowing more time for digestion before a race was the only way the body enzymes could fully digest the body food.

In evaluating the influence of 7,340 feet on the performance capacity of top athletes during extended work, Nerdrum, Benum, Oseid, and Sommerfeldt studied a group of long and middle-distance runners during work at sea level and in a low pressure chamber at a simulated altitude of 7,340 feet. The work was part of an investigation to determine the biochemical response of the human organism to heavy work, and biochemical parameters mainly have therefore been determined.

The group was comprised of 12 nonacclimatized Norwegian top runners, all having undergone hard training with increasing intensity for the last 5 - 6 years or more. Particulars about the group are given in Table I.⁴

⁴Nerdrum, H. J., P. Benum, S. Oseid, and S. Sommerfeldt. "Biochemical Parameters in Work Tests Under Various Barometric Pressures," The Effect Of Altitude On Physical Performance. (Chicago: The Athletic Institute, 1967), p. 17.

TABLE I
ATHLETES PARTICIPATING IN THE TEST

<u>INITIALS</u>	<u>AGE</u>	<u>DISTANCE</u>	<u>BEST TIME</u>
M. B.	20 yrs.	1,500 m	3.52.4
S. R.	27 yrs.	1,500 m	3.40.6
K. H.	26 yrs.	1,500 m	3.51.9
T. S. N.	21 yrs.	1,500 m	3.48.1
B. O.	26 yrs.	1,500 m	3.50.9
A. K.	21 yrs.	1,500 m	3.42.1
T. H.	30 yrs.	10,000 m	29.27.6
P. B.	31 yrs.	10,000 m	29.13.6
P. L.	29 yrs.	10,000 m	30.06.4 (Marathon)
E. M.	27 yrs.	10,000 m	31.56.6 (Marathon)
H. O.	24 yrs.	10,000 m	30.26.0
K. B.	25 yrs.	10,000 m	30.28.6

The above group was composed of 12 nonacclimatized athletes ranging in age from 20 - 31 years. Six of the athletes competed in the 1,500 meter run, and six competed in the 10,000 meter run.

The following test conditions were used: The athletes were first worked continuously on an ergometer cycle for 18 minutes, the work starting at 360 Kpm/min., increasing after 6 minutes to 730 Kpm/min. and after another 6 minutes ending up with 6 minute submaximal load of 1,440 Kpm/min. After a 4 minute rest, a 3 minute maximal load, individually varying between 2,000 and 3,000 Kpm/min. was taken.

Apart from the difference in air pressure, identical test conditions were used at sea level and in the low pressure chamber.

Nerdrum, Benum, Oseid and Sommerfeldt indicated that there were biochemical changes which affected the body organisms.

TABLE II
RESULTS OF ERGOMETER STUDIES

PARAMETER		REST	SUBMAX.	MAX.	RECOVERY
pH	SL	7.41	7.36	7.24	7.37
	LPC	7.41	7.33	7.22	7.37
pCO ₂	SL	35.00	36.00	34.50	33.50
	LPC	35.60	36.00	33.80	34.50
HCO ₃	SL	23.00	20.00	15.50	20.40
	LPC	23.10	19.20	14.40	20.00
Lactate	SL	25.00	43.30	103.80	65.90
	LPC	25.40	55.80	91.40	57.80

As you can see, at SL there was a slight decrease in pH and standard bicarbonate, a slight increase in the lactic acid concentration, indicating that the workload chosen was very close to the maximal work this individual could do for an extended period of time.

From the ergometer test value at LPC, it can be observed that a higher lactic acid concentration and a lower pH and standard bicarbonate are seen at submaximal work, indicating that the work was being done more anaerobically.

The same tendencies can be seen after maximal work, though average lactate values for unknown reasons were slightly lower in LPC. Phosphorus carbonate varies little and the average recovery values were not much different at SL and in LPC.⁵

From this test it seemed probable that the differences in general as well as the relatively great individual differences in biochemical response to physical work at sea level and in low pressure chambers at 7,340 feet, reflected a similar difference in performance capacity during competition.

There was a difference from the SL to LPC on the non-acclimatized athlete; but further study is needed to help determine biochemical response to work.

In the study by Dr. Favour on problems which arise during maximum exertion under hypoxic conditions, the biggest surprise they found was the phenomenon of the deterioration of the third day at altitude, particularly after exertion. This deterioration was most manifest in the lactic acid ventilatory aspect.⁶

From this study, one tends to believe that athletic competition should be either on the first day or after at least a week of acclimatization.

Dr. Favour's subjects felt ill effects such as headache, insomnia, somnolence, nausea, vomiting, diarrhea, forgetfulness, and lack of drive on the third day of acclimatization. He again felt that fitness did not prevent some degree of deterioration on the third day, but the top athlete will be able to adapt and adjust quicker than the unfit athlete.⁷

⁵Ibid., p. 18.

⁶Favour, Cutting B. "Lactic Acid, Fitness and Altitude," The Effects of Altitude on Physical Performance, (Chicago: The Athletic Institute, 1967), p. 20.

⁷Ibid., p. 23.

Fitness again does not seem to make an appreciable difference at altitude in getting O_2 to the blood nor in expiring CO_2 . The less the tissue hypoxia during exercise, the less the lactic acidemia with severe exertion.

Dr. Favour concluded that a modest program of physical training for sedentary young men will reduce the lactic acidemia which occurs both at rest and during exertion at 14,150 feet.⁸

As stated in the three previous articles, the digestive system along with its parameters are not greatly affected by the high altitude problem. There are some areas which reacted unfavorably to acclimatization in a small way, but not enough to cause great concern.

As of this point very little is known as to why the digestive function reacts the way it does at high altitude. The authors of the articles all seem to agree that further laboratory and field studies are needed.

The cardiovascular system again received great discussion when in relation to whether or not altitude had a direct or indirect effect on its function.

Dr. James Vogel and Dr. James E. Hansen conducted a study in the fall of 1964 with twenty-four healthy, young male, non-obese subjects who were life-long sea level residents. They wanted to study the cardiovascular aspects of early acclimatization to an altitude of 4,300 meters (Pikes Peak, Colorado) in young men at rest and during exhaustive exercise. The twenty-four subjects were then divided into groups of eight: one group remained at sea level, another group which was transported abruptly to Pikes Peak (4,300 m.), and a final group which was moved gradually with one week intervals at 1,640 and 3,475 m. to Pikes Peak. Each group was then divided in half: 4 assigned to an increased physical training program and 4 to a reduced physical activity program.

⁸Ibid., p. 23.

The increased physical training group exhibited a significantly lower heart rate during rest and throughout the study. Stroke volume on the other hand, was significantly influenced by change in altitude and also by the rate of ascent. Dr. Vogel stated that during the first week at 4,300 m., stroke volume was unchanged from sea level values at rest, mild exercise and recovery, but was significantly elevated at moderate and maximum work.⁹

Systolic and diastolic blood pressure increased slightly but significantly upon going to high altitude. Systolic blood pressure did not change at rest in either run at 4,300 m., but did increase during mild and moderate work and during recovery. Pulse rate remained unchanged.

Increase in cardiac output was an early response elicited by the body in adapting to an environment of reduced oxygen tension.

Dr. Hansen stated that a marked vasodilatation of peripheral vascular beds was used in facilitating blood flow during hypoxemia. This not only reduced resistance to flow and maintained a relatively normal blood pressure, but also reduced the distance between the hemoglobin molecule and active tissue cell. It may also be that the actual initiating and controlling stimuli for the heart rate and stroke volume responses during hypoxia originate primarily from the peripheral vascular bed rather than from central sites.¹⁰

The rate of ascent has an important influence on these cardiovascular responses but not physical conditioning.

It can be concluded from Dr. Vogel and Dr. Hansen's article that the heart and circulation are quite capable of meeting the demands of oxygen delivery during heavy work at altitudes up to 4,300 m. There was not any evidence shown of deleterious effects on the circulatory system or any reduced efficiency in the heart's action.

¹⁰Ibid., p. 49.

In concluding this article further, on which rate of ascent was more beneficial, one could conclude that a gradual rate of ascent proved more advantageous because it reduced the workload on the heart.

It was stated by Astrand and Salten that the aerobic capacity and maximal heart rate were the same on maximal running when the athlete was well trained.¹¹ If this was true, then most countries who went to the high altitude for athletic competition should have very little problems with their athletes who were well trained. This is not to say, though, that the heart rate was not affected. There was a decrease in the heart rate at altitude, but not a sufficient amount to affect the runner.

The pulmonary system of the body has received a little more attention on the effects of going to high altitude during the last ten years. This has been due to the occasional occurrence of acute pulmonary edema. One may acquire this effect when traveling within a day or two from sea level to 9,000 feet or more. This illness usually occurs 6 - 36 hours after arrival at high altitude.

Dr. Hultgen suggested that a gradual ascent should be taken in order for the individual to become acclimatized. After arrival a period of rest should be taken for one or two days in order for the body to adjust itself. The first sign of a cough or undue dyspnea should receive immediate medical attention.

Heavy physical work at high altitude even in well acclimated people could result in pulmonary edema. The athlete who trained short hours over long periods of time should not be effected by this illness.

¹¹ Astrand, P. O., and B. Salten. "Oxygen Intake and Heart Rate in Various Types of Muscular Activity," Journal of Applied Physiology, 16 (6): 1961, p. 977.

Hultgen felt that acclimatized persons who spend more than 10 days at sea level and then return to high altitude may be susceptible to pulmonary edema upon re-ascent.¹²

In studying the evidence on pulmonary edema it would be advisable when training for high altitude competition that the athlete become acclimatized slowly and work at moderate rates.

The well-trained athlete, such as those who competed in Mexico City this past year, could do more work at altitude; but his performance decrement was approximately on the same percentage basis as was the decrement for poorly trained men.

In a study by Buskirk, Kollias, Piconreatique, Akers, Prokop, and Baker, they took six track athletes who began a control program at Penn State at the height of their spring competition. They remained in training throughout their summer's stay at altitude. On return to Penn State, they immediately commenced training for cross-country.

In the tests given to these athletes, at the different altitudes, a number of conclusions were discovered: as far as heart rate, ventilation, oxygen debt, and maximal oxygen intake were concerned:

- a. Heart rate was essentially the same at all altitudes.
- b. Maximal oxygen intake was reduced at altitude but maximal heart rate remained constant.
- c. Oxygen pulse rate was reduced.
- d. Oxygen debt was slightly less at 13,000 feet than at Penn State.

¹²Hultgen, Herbert N., "High Altitude Pulmonary Edema," The Effects of Altitude on Physical Performance (Chicago: The Athletic Institute, 1967), p. 53.

After returning to Penn State, the subjects felt that their breathing was "free and easy" but their legs bothered them, particularly during sprints and other routines requiring anaerobic effort. These complaints disappeared after about three weeks of training.

Another point the authors were trying to discover was to see if after returning from altitude, the athletes performed better than before leaving for altitude. It was noted that there was little evidence to indicate that such performance on return from altitude is better than before going to altitude, if training remains constant.¹³ There was certain cases which showed some improvement, but it was probably due to individual difference.

Frank Potts, track coach at the University of Colorado, tends to agree that altitude did have an effect on a boy's performance. He felt that the major effect was on the recovery rate of the individual. The higher the altitude, the longer it took to recover.

Coach Potts felt that any race under two minutes should not be effected by the altitude, but a race of two minutes or more had an effect on the body. He estimated that in the mile run, at Colorado, a boy who ran 4:25 could run under 4:20 at a lower altitude.

The psychological point of coming up from a low altitude to a high altitude had, to some degree, an effect on a performer. If a boy felt that he was going to run a bad race, he generally did just that. Ordinarily a good runner would win. If a good runner could win at sea level, he could win at altitude.

¹³ Buskirk, E. R., J. Kollias, E. Piconreatique, R. Akers, E. Prokop and P. Baker, "Physiology and Performance of Track Athletes at Various Altitudes In The United States and Peru," The Effects of Altitude on Physical Performance, (Chicago: The Athletic Institute, 1967), p. 65.

In a study by Soni, Rivera, and Mendoza three professional athletes were used to see if there was any evidence of dangerous changes during performance of exercise in Mexico City.

It was concluded after a great amount of study that increase in altitude imposed added work on the heart and lungs of the non-acclimatized athlete. They went on to say that the non-acclimatized individual may be able to perform at his maximum of efficiency in prolonged events without harm. Effort at this altitude, even strenuous exercise was not harmful.¹⁴

From this study, one could assume that in good physical condition, an athlete will overcome the problems of altitude with acclimatization very readily.

Grover and Reeves came up with an interesting study in which two track teams were compared from different altitudes, running first at altitude and second at sea level.

The first track team was from Lexington, Kentucky, altitude, 300 meters or 1,000 feet, the second group of athletes were from Leadville, Colorado, altitude, 3,100 meters or 10,200 feet. Results of this experiment are shown in the table on the following page.

¹⁴ Soni, Jorge, Ignacio Chavez Rivera, and Felipe Mendoza, "The Effects of Altitude on Non-Acclimatized Athletes During Effort," The Effects of Altitude on Physical Performance (Chicago: The Athletic Institute, 1967), p. 79.

TABLE III
PHYSICAL CHARACTERISTICS OF ATHLETES

	Five Athletes Native To 3,100 Meters	Five Athletes Native To 300 Meters
Age - Yr.	17	17
Height - cm.	176	175
Weight - Kgm.	68	66
Heart Vol-ml.	950	980
Hemoglobin gm. %	17	16
Hematocrit %	47	46
R B C ml/mm ³	5.7	5.3
Lung Vol. - l	7.2	6.6
Vital Cap. - l	5.1	5.1
D _L CO	61	56
VO ₂ max. (ml/kg/min.)	66	68

Table III shows the physical characteristics of the athletes and their similarity.¹⁵ The average age of both groups was 17 years. They ranged in height from 176 cm. for the Leadville group to 175 cm. for the Lexington group. Their weight in Kgm. ranged from 68 for Leadville to 66 Kgm. for Lexington. The hemoglobin per cent in gm. was about equal for both groups along with the hematocrit per cent.

¹⁵Grover, Robert, John T. Reeves. "Exercise Performance of Athletes at Sea Level and 3,100 Meters Altitude," "The Effects of Altitude on Physical Performance" (Chicago: The Athletic Institute, 1967) p. 80.

Heart Vol-ml. for the Leadville group was 950 to 980 for the Lexington group. Respiratory capacity (R B C) was 5.7 for Leadville to 5.3 for Lexington. Lung Vol. ranged from 7.2 for Leadville to 6.6 for Lexington. Vital Cap. was equal for both groups at 5.1. Diffusing capacity ($D_L CO$) was 61 for the Leadville group to 56 for the Lexington team. Maximum oxygen uptake (VO_2 Max.(ml/kg/m.) at low altitude was 66 for the Leadville team to 68 for the Lexington team. This indicated that Grover and Reeves were dealing with young men whose physical work capacity was very high.

TABLE IV
RUNNING TIMES FOR TRACK EVENTS
AT 300 METERS AND 3,100 METERS ALTITUDE

		Lexington Team		Leadville Team	
Running Distance		Altitude Meters 300 3,100		Altitude Meters 300 3,100	
Yards	Meters	Time Min:Sec		Time Min:Sec	
220	201	0:24.0	0:22.4	0:25.7	0:27.0
440	402	0:54.0	0:51.0	1:03.5	0:52.5
880	804	2:10.0	2:11.5	2:24.7	2:30.0
1760	1509	4:49.0	5:10.9	5:23.5	5:35.0

Since there was such similarity between the two groups, one would expect that the acclimatized person to have a distinct advantage. In every event during track competition, the Lexington man was faster than the Leadville man at both low and medium altitude. Table IV shows the comparison between the two groups.

Grover and Reeves also indorsed the idea that no matter what the altitude, the superior athletes would win the event in spite of the altitude. As can be seen from Table IV, the times were slower at the medium altitude on both groups, but were won by the superior athlete.¹⁶

Of particular note to people from the plains area, Conrad Nightingale, a member of the 1968 U. S. Olympic Team, and Jim Ryan, World Record Holder in the mile run, both felt that altitude did effect their performance. Both runners seemed to agree that they reached their oxygen debt sooner and thus in turn, slowed their performance.

They also felt you couldn't run the same type of race at sea level as you did at altitude. The race at altitude had to be run slower in order that they didn't burn their energy up too early.

Both athletes felt that when competing at altitude, one must train at altitude for maximum performance.

Saltin also felt that a long acclimatization period was very important for a successful and risk-free participation in competition at altitude.

Saltin felt that any competition in endurance events should not be held at 2,250 meters. He did not believe this because it may cause injury; he just felt that it was not fair to the athlete.

In a study on "Acclimatization to Altitude in Japanese Athletes," Asahina, Ikai, Ogawa, and Kuroda, wanted to find out how many days were necessary to become acclimatized in order to perform endurance events as effectively as possible at medium altitude.

¹⁶Ibid., p. 85.

Here again, they felt that from two to three weeks were necessary in order for the endurance athlete to become acclimatized. As for short events and jumping events, they felt that altitude did not have a great effect on physical performance.

Dr. Bynum's study on "Work Capacity of Altitude Acclimatized Men at Altitude and Sea Level," showed that upon descending from an elevation of 5,170 feet, a highly conditioned altitude acclimatized man would probably experience the following:

1. A reduction in resting pulse rate.
2. No change in resting ventilation rate.
3. Following an all-out treadmill run he would probably experience no change in terminal pulse rate.
4. He would be able to increase his treadmill run time (or work capacity) without increasing his recovery pulse rate.
5. He would be able to perform at a higher cardiorespiratory work level than he was capable of at altitude.¹⁷

In analyzing these results, one would have a tendency to believe that in order to compete well at sea level, one must be conditioned at high altitude. There was a considerable amount of disagreement on whether this did have an effect, but most authorities felt that there wasn't a substantial difference to affect the performance.

There was a slight effect of altitude on the physical performance of a runner who came from sea level to medium altitude, but proper training will, for the most part, counteract the side effect of the body.

¹⁷ Bynum, W. A., "Work Capacity of Altitude Acclimatized Men at Altitude and Sea Level," The Effects of Altitude on Physical Performance, (Chicago: The Athlete Institute, 1967) p. 80.

Evidence indicates that for the most part, if athletes are to compete well at altitude, they must:

1. Be in top physical condition.
2. Train at altitude.
3. Allow for a period of acclimatization of 2 or 3 weeks.
4. Prepare mentally for altitude competition.
5. Have a good environmental factor.

If these and other training recommendations were followed, there shouldn't be any serious effect on the athlete's performance.

SUMMARY AND CONCLUSION

Many tests, beliefs, and questions were presented in this study to show the effects of altitude on the physical performance of the body at altitude.

The body systems had very little effect when being subjected to different altitude levels. It was noted that proper care should be given if any effect does arise.

Acclimatization to an altitude was a must before an athlete competed at his peak. In most cases, it took a training period from two to three weeks for a person to become acclimatized.

For best results, it was shown that a gradual rate of ascent was better for the environmental adjustment.

Competition at sea level was somewhat faster than at altitude, but the psychological effect had a lot to do with the performance. There was a difference in total performance.

The rate of descent had very little to do with the total body performance and its effect. On whether performance was better after training at altitude and competing at sea level, there was little difference and very little evidence to support the belief.

Recommendations for one to compete well at altitude are as follows:

1. Be in top physical condition.
2. Train at altitude (especially distance athletes).
3. Allow for a 2 - 3 week acclimatization period.
4. Prepare mentally for altitude competition.
5. Good environmental factors.

If these and other training recommendations were followed, there shouldn't be any serious effect on the athlete's performance. It still was figured to the same old proverb, "the best man wins."

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In writing this paper, the author compiled a comparative study of what authorities felt on the Effects of Altitude on Physical Performance.

The first purpose of this study was to summarize certain articles pertaining to the effect of altitude on physical performance. Second was to point out the different authors beliefs as to what extent altitude does effect the body and its organisms. Third, was to point out what the authorities said *would be the best training to prepare for altitude competition.*

The results of this study were that many authorities felt that the body systems such as the digestive, cardiovascular, and pulmonary systems, had very little effect on the total body performance. There was not enough evidence to support the idea that the system can hurt the athletic performance at high altitude.

A period of two to three weeks should be used in order for the body to become acclimatized to the new altitude and allow for the performer to compete at his best.

Studies were given to show that a gradual rate of ascent was the most beneficial to an athlete. Studies were also given to show that the rate of descent and training at altitude for competition at sea level had little effect on athletic performance.

Finally, the recommendation for best athletic competition results at altitude were given. They were as follows:

1. Be in top physical condition.
2. Train at altitude (especially distance athletes).
3. Allow for a two-three week acclimatization period.
4. Prepare mentally for altitude competition.
5. Good environmental factors.

In the majority of the studies and articles which I compared, most authorities tend to feel that there would be little effect on the body system in relation to altitude.