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Effects of Altitude Acclimatization on Cardiorespiratory Fitness in McPherson College Women's Soccer Players

Whitney Williams

ABSTRACT

To study the effects of altitude acclimatization on cardiorespiratory fitness, 12 healthy female college soccer players at McPherson College were selected to complete the Harvard Step Test when acclimatized two different altitudes. We investigated how strongly altitude acclimatization affects cardiorespiratory fitness in the form of heart rate recovery after intense exercise upon long-term acclimatization to a relatively higher and lower altitude. Results showed an overall slight positive correlation between altitude of acclimatization and change in cardiorespiratory fitness. Although positive, we suspect that the variability in fitness regimens between different subjects could have skewed the results. For future consideration and better consistency, the use of more subjects and better defined fitness regimens are recommended.

Keywords: *Altitude Acclimatization, Cardiorespiratory Fitness, Harvard Step Test.*

INTRODUCTION

It has been well known for decades that training at high altitudes is more beneficial for athletic performance than training at low altitudes. High altitude exposure has been suggested to induce changes in substrate utilization during moderate intensity exercise in humans, leading to an enhanced reliance on carbohydrate (CHO) utilization, which is thought to be advantageous (Lundby et al. 2002). At higher altitudes, the atmospheric pressure is lower and therefore the air is thinner and contains less oxygen per cubic unit. A given work rate performed at sea level will be relatively higher when performed this altitude, and the reverse is also true (Lundby et al 2002).

Altitude training is frequently used by competitive athletes to improve lower altitude performance (Levine et al. 1997). Athletes training in these hypoxic environments will adapt to be able to utilize what little oxygen they can breathe in. Acclimatization to high altitude results in central and peripheral adaptations that improve oxygen delivery and utilization (Levine et al. 1997). When they return to lower altitudes, these adaptations will lead to improve performance because of the seeming abundance of oxygen. These adaptations can include enhanced oxygen uptake in the lungs, lung compliance, and pulmonary diffusion as well as elevated hemoglobin concentrations (de Meer et al. 1994).

McPherson, Kansas is at an elevation of 1,496 ft (Google Earth) which considered low-medium altitude. McPherson College Athletes will typically experience two different effects on their performance at different altitudes: physiological and mechanical. The second is not very pronounced and only applies to specific sports (such as sprinting or throwing events in track and field competitions). The first effect mentioned applies to endurance sport. College women soccer programs often consist of around 20 young women between ages 18 and 22.

The purpose of the study is therefore to use the Harvard Step Test to examine the cardiorespiratory fitness of the subjects both when acclimatized to McPherson's altitude of 1,496 ft and again when acclimatized to a different altitude (in most cases, significantly higher). This other altitude will be determined using the home addresses provided by the subjects and the Google Earth computer program. Step tests have been widely used to assess cardiorespiratory fitness. The Harvard Step Test was chosen because it requires minimal equipment and costs and is relatively simple to perform, as well as for its validity (correlation to VO2max is approximately 0.6 to 0.8) (Top End Sports. 2007). Work rate is determined by step height (18 inches) and step frequency (120 per minute), whereas the total amount of work done depends on the number (1) and duration (5 minutes) of work periods. Performance is based on heart rate during recovery (Watkins 1984). This test, described in more detail in the materials and methods, involves a rigorous and controlled five-minute exercise followed by three heartbeat counts taken at specific times. The data is put through a mathematical equation and formulated into scores. These scores are assigned values (see Table 1) when the test is applied to the general public, but for the purpose of this experiment, the raw numerical scores will be used. The results of both tests for each subject were compared and t-tested for statistical significance regarding the effects of altitude acclimatization on cardiorespiratory fitness.

MATERIALS AND METHODS

This study involved 12 female soccer players at McPherson College in McPherson, Kansas, all between the ages of 18 and 21. The sample size is

Table 1. Harvard Fitness Score Test Interpretations

> 90	Excellent
80-89	Good
65-79	High Average
55-64	Low Average
< 54	Below Average

relatively small, but in the cited paper by Lundby and Hall (2002), 8 trained subjects proved sufficient for their purposes, which were similar to mine. All subjects gave their informed consent before participation. The study was approved by the McPherson College Natural Sciences department and Cantaurus committee.

In the process of testing for how altitude acclimatization affects the cardiorespiratory fitness levels of McPherson College female soccer players, many variables came up, including age, natural fitness level, competitiveness, and degree of acclimatization, and to what altitude. But since a college soccer program is essentially a "melting pot" of young women, it is impossible to have a control subject on which to base the results of others. They were therefore each their own control subject, taking data at two different key points in the year. These two key points were 1) before summer break, when they were all acclimatized to McPherson's altitude and had undergone the same conditioning program, and 2) after summer break, when they returned home, or to somewhere other than McPherson, for 3 months to the altitude they acclimatized to for the final testing.

Official off-season mandatory training for the subjects started January 2009 and ended May 2009. This training consisted of cardiorespiratory conditioning sessions (such as sprints or long distance running), weight lifting, and playing soccer frequently. Since this fitness regimen was the same for each player, all players were considered equally fit for the test.

At the end of off-season training, the first fitness test was performed. The test chosen was the Harvard Step Test (Brouha *et al*. 1944). This is the earliest reported step test and was originally designed to determine aerobic fitness of undergraduate male students. This test called for a 20 inch (50.8 cm) high bench or platform, a stopwatch, and a metronome or cadence tape. Because the original test did not take the size of the athlete into account, and because the subjects for this experiment were all young women of average height, the platform used was a wooden chair 18 inches tall (no arm rests). For safety reasons, a third party was used to hold the chair in place to avoid the risks of slipping or tipping. The subjects were instructed to step up and down from the platform with both feet at a rate of 120 steps per minute, following the beat of the metronome, for 5 minutes (600 steps total). Once the 5 minutes was up, they were told to immediately sit and rest. They then took their pulse for 30 seconds at the one, two, and three minute marks after the test was completed. These counts were multiplied by two so that they were in beats per minute. Then, to find the score of the test, those numbers were entered into the following equation:

$$30{,}000 \div [\text{pulse1} + \text{pulse2} + \text{pulse3}]$$

These results were recorded for each individual and saved as the control values to compare with the post-summer testing.

At the end of the school year, the players each returned to their respective homes, or somewhere else outside of McPherson, KS, located all over the country at all different altitudes. These altitudes were recorded prior to experimentation using Google Earth. Also during this period, each player was given identical training regimens with a daily exercise schedule that they were assumed to have followed strictly.

After the summer, all players returned to school for pre-season training week. This week involved three fitness tests in addition to three practice sessions per day. Because of this intense first week, the second testing was not done until 1.5-2 weeks after returning to McPherson, in order to avoid skewed results caused by the fatigue the subjects. This time period should not have an affect on the results because it takes 3-4 weeks to fully acclimatize to a different altitude (Lundby *et al*. 2002).

RESULTS

To analyze my data, I organized the subjects into two groups according to their change in altitude for the acclimatization period, with McPherson as the 'zero' starting point. This is summarized in Table 2. I subtracted the score of the first test from the score of the second test to find the difference for each subject. Most subjects showed an increase in score, resulting in a positive difference; 3 subjects showed a decrease in score. Next**,** I tested for significance difference using a paired T-test at a significance of alpha = 0.05. This is all summarized in Table 2.

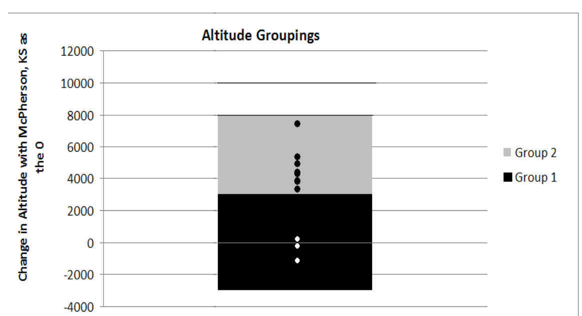

Figure 1. Grouped subjects according to altitude with McPherson, KS as the zero line.

Table 2. Grouped subjects, scores, and p-value

	Change in Altitude Range	1st Score	2nd Score	Difference	P-Value
Group 1	-3000 ft to +3000 ft	88.8	92.3	3.5	0.027
		73.5	75	1.5	
		73.2	75.4	2.2	
Group 2	+3001 ft to +8000 ft	109.5	91.5	-18	0.384
		81.5	101.4	19.9	
		77.7	88.2	10.5	
		72.1	76.9	4.8	
		69.1	88.2	19.1	
		81.1	88.8	7.7	
		104.9	71.8	-33.1	
		88.8	97.4	8.6	
		89.3	85.7	-3.6	

In group 2, the first and seventh score differences are very unusual from the rest of the group, and so they were removed from the data table for statistical purposes. This is shown in Table 3.

Table 3. Results with extreme data points removed

	Change in Altitude Range	1st Score	2nd Score	Difference	P-Value
Group 1	-3000 ft to +3000 ft	88.8	92.3	3.5	0.027
		73.5	75	1.5	
		73.2	75.4	2.2	
Group 2	+3001 ft to +8000 ft	81.5	101.4	19.9	0.01
		77.7	88.2	10.5	
		72.1	76.9	4.8	
		69.1	88.2	19.1	
		81.1	88.8	7.7	
		88.8	97.4	8.6	
		89.3	85.7	-3.6	

DISCUSSION

In Table 2, the p-value for group 1 is .027, which is less than .05, indicating a significant trend in score differential. The p-value for group 2, however, is .384, well above .05. This is largely because of the extreme outliers in the data. Because these outliers were identified as being related to something other than the control variable, they were removed from the data. After this was done, the p-value for group 2 became .01, indicating a very significant trend in score differential.

The results found in this study can be explained by several physiological processes. In the case of the single subject that went down in altitude (in group 1), there was a negative correlation between altitude change and score change. It was expected that the acclimatization to lower altitude would be disadvantageous because there is less oxygen at the testing altitude than where she spent the summer. This result could have also been partly attributed to the above average fitness regime of the subject during the acclimatization period (meaning that she exercised more often and more vigorously than the majority of other subjects-personal communication), as well as the delay between arrival at the testing altitude and the actual testing. The results of the two subjects that stayed near the testing altitude (in group 1).followed the expected results: only very slight changes in score. The results of the subjects that went up in altitude (in group 2) were somewhat confusing. They all should have had enhanced oxygen uptake in the lungs, lung compliance, and pulmonary diffusion, as well as increased hemoglobin levels. These changes are because of the smaller amounts of oxygen in the air available for respiration. These changes should have been very advantageous when returning to the testing altitude, at which the air is comparatively saturated with oxygen, making respiration easier and heart rate lower (better scores). Reasons for difference in results this can be explained by the fitness regimes of the subjects during the acclimatization period, as well as the delay between arrival at the testing altitude and the actual testing.

The results of this study followed what was expected. The one subject that went down in altitude showed a negative correlation in score change, as did one subject of the two that had little/no change in altitude and three of the nine subjects that went up in altitude. These negative correlations were further investigated and found to have been affected by the level of summer conditioning carried out by each individual subject (this same investigation was not carried out for the positively correlating subjects). Overall, the majority of subjects showed positive correlations (7 out of 12). It is difficult to tell whether these results can be replicated because of the small sample size. In the future, further research with a larger sample size will greatly help to study how altitude acclimatization affects cardiorespiratory fitness in McPherson college women.

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