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THE EFFECT OF MODERATE ALTITUDE ON HIGH INTENSITY RUNNING
PERFORMANCE DURING A GAME WITH COLLEGIATE FEMALE SOCCER PLAYERS

by

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B.S. University of Central Florida, 2012

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ABSTRACT

Competition often requires teams that reside at sea level to compete against opponents whose residence is at a moderate altitude. This may pose a potential competitive disadvantage considering that moderate altitude may cause decrements in $\text{VO}_{2\text{max}}$, distance covered, and time to exhaustion in endurance athletes. The purpose of this study was to examine the effect of altitude on game performance measures.

Six NCAA Division I female soccer players (20.33 ± 1.21 y; 168 ± 6.45 cm; 62.5 ± 6.03 kg) were retrospectively examined. Comparisons were made between two competitions that were played at sea level (SL) within two weeks of a game played at a moderate altitude (1840 m) on game characteristics including high intensity running (HIR) and total distance covered (TDC). Analysis was performed on these six players who met a threshold of playing sixty or more minutes in each competition. A 10-Hz global positioning system (GPS) was used to measure distance and velocity. The rate of TDC and HIR during the game ($\text{m}\cdot\text{min}^{-1}$) and percentage of time at HIR during competition were evaluated. The two games at SL were averaged to establish baseline performance and the mean results were compared with the single game played at altitude. Paired samples t-tests were performed to determine if any mean differences existed between performance at altitude and sea level.

Significant differences ($p < 0.05$) were seen in minutes played between the games at SL (74.23 ± 2.93 min) versus altitude (83.24 ± 5.27 min). The relative distance rate during the game at altitude was lower at altitude (105.77 ± 10.19 $\text{m}\cdot\text{min}^{-1}$) than at SL (120.55 ± 8.26 $\text{m}\cdot\text{min}^{-1}$). HIR rate was greater at SL (27.65 ± 9.25 $\text{m}\cdot\text{min}^{-1}$) compared to altitude (25.07 ± 7.66 $\text{m}\cdot\text{min}^{-1}$).

The percent of time spent at high intensity was not significantly different ($p = 0.064$), yet tended to be greater at sea level ($10.4 \pm 3.3\%$) than when they performed at altitude ($9.1 \pm 2.2\%$).

Soccer performance at a moderate altitude appears to reduce the rate at which players run throughout the competition, as well as their rate at a high intensity. Results suggest that teams that reside at SL may be at a competitive disadvantage when competing at altitude.

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TABLE OF CONTENTS

LIST OF FIGURES	ix
LIST OF TABLES	x
LIST OF ACRONYMS/ABBREVIATIONS	xi
CHAPTER I.....	1
Introduction	1
Hypothesis	3
Delimitations	4
Limitations	4
Theoretical Assumptions.....	4
Statistical Assumptions	5
CHAPTER II.....	6
Literature review	6
High Intensity Running at Altitude	7
Metabolic Demands of High Intensity Running.....	8
High Intensity Running and Field Sports	9

Soccer Performance at Altitude.....	13
CHAPTER III.....	15
Methodology.....	15
Experimental Design.....	15
Participants.....	16
Game Data Collection.....	17
Velocity Zones.....	17
Statistical Analysis.....	18
CHAPTER IV.....	19
Results.....	19
CHAPTER V.....	22
Discussion.....	22
Conclusions.....	25
APPENDIX: UCF IRB APPROVAL LETTER.....	26
LIST OF REFERENCES.....	28

LIST OF FIGURES

Figure 1: Rate of Total Distance Covered	19
Figure 2: Rate of High Intensity Running.....	20
Figure 3: Percent Time at High Intensity Running.....	21

LIST OF TABLES

Table 1: Competition Descriptives	16
Table 2: Velocity Zones	18

LIST OF ACRONYMS/ABBREVIATIONS

AOD	Accumulated Oxygen Deficit
EST	Eastern Standard Time
FIFA	Fédération Internationale de Football Association
GPS	Global Positioning Systems
HIR	High Intensity Running
Hz	Hertz
km	Kilometers
km·h ⁻¹	Kilometers Per Hour
m	Meters
MST	Mountain Standard Time
m·min ⁻¹	Meters Per Minute
NCAA	National Collegiate Athletic Association
TDC	Total Distance Covered
VO _{2max}	Maximal Oxygen Uptake

CHAPTER I

Introduction

The game of soccer incorporates both aerobic and anaerobic components which need to be sustained throughout competition (Billaut, Gore, & Aughey, 2012; Gore, McSharry, Hewitt, & Saunders, 2008; Krstrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mohr, Krstrup, & Bangsbo, 2003). A standard elite soccer game involves two separate forty five minute halves, which are only interrupted by a substitution or injury timeout. This maintains fairly continuous gameplay requiring significant aerobic endurance, interspersed with explosive bouts of sprinting (Bradley et al., 2009; Krstrup et al., 2005; Mohr et al., 2003). This change in pace and exertion, as well as a player's ability to recover from repetitive sprints is critical to game performance. Krstrup et al. (2005) found that elite female soccer players performed between 72 - 159 high intensity runs, accounting for an average of 1,310 m and nearly 5% of the competition time. In addition, elite female soccer athletes are reported to run approximately 10 km on average during competition, with approximately 95% of the game performed at a low intensity, which was defined as standing, walking, or running below $15 \text{ km}\cdot\text{h}^{-1}$.

Athletic performance appears to be affected when competing at altitude (Bärtsch, Saltin, & Dvorak, 2008; Daniels, 1979). The acute physiological changes associated with varying altitudes above sea level may have significant effects on performance, especially on athletes that are not acclimated (Wehrlin & Hallén, 2006). Acute performance at altitude can impair aerobic performance and increase the rate of fatigue for athletes who ascend from sea level. For instance, Werhlin and Hallén (2006) examined a simulated change in altitude from 300 m to 2,800 m and

reported a significant decrease in oxygen saturation, time to exhaustion and VO_{2max} during exercise at altitude. At altitude, a decrease in partial pressure of oxygen will increase pulmonary ventilation, but oxygen uptake by muscle is still impaired due to a reduced diffusion gradient (Grover, Weil, & Reeves, 1986). In addition, individuals ascending to altitude also experience a decrease in stroke volume and to compensate an increase in heart rate (Buchheit et al., 2012; Grover et al., 1986). Depending upon the altitude, these cardiovascular changes can cause significant performance decrements in activities that are primarily dependent upon aerobic metabolism. In regards to high intensity activity such as sprints, evidence suggests that sprint performance may be enhanced due to the lower air resistance, which results in less drag (Arsac, 2002; B. Levine, Stray-Gundersen, & Mehta, 2008; Peronnet, Thibault, & Cousineau, 1991). However, the ability to recover from multiple sprints may be affected by the reduced cardiovascular ability seen at altitude. This potentially has important implications for competitions played at altitude.

Interestingly, living at altitude results in specific physiological adaptations (e.g. increases in red blood cell production, hemoglobin concentrations, blood volume and buffering capacity) that enhances cardiovascular performance that may provide a distinct advantage for an athlete that resides at altitude (B. D. Levine & Stray-Gundersen, 1997). For sports such as soccer, competitions at altitude may present a distinct disadvantage for teams that are required to travel compete at altitude (Bärtsch et al., 2008; McSharry, 2007). Due to a concern for a potential performance advantage for teams residing at altitude, the Fédération Internationale de Football Association (FIFA) has considered a ban on international matches at elevations over 2500 m (McSharry, 2007). Nassis (2013) has reported that the total distance covered in a soccer game

was decreased up to 3% at altitudes above 1200 m. However, the number of studies that have examined the effects of acute competition at altitude are limited. Some studies have observed high intensity running and analyzed game performance using videotape to quantitate movement in competition (Bradley et al., 2009; Krustup et al., 2005; Mohr et al., 2003). The outcomes of these studies suggest that exertion rate and frequency of high intensity running among elite soccer players is altered during competition with an earlier onset of fatigue observed. However, technological advances in analyzing physiological performance variables through the use of global positioning systems (GPS) provides a more sensitive measure for monitoring performance in multiple players during actual competitions. Thus, the purpose of this investigation is to compare the effect of altitude on the rate of high intensity running and distance run during competitive games in women's intercollegiate soccer.

Hypothesis

It was hypothesized that acute exposure to altitude would decrease performance in the total distance rate (m/min) and the rate of HIR (m/min) through the progression of competition. Due to the length of an elite soccer game, and the higher intensity activity profile observed in elite female soccer players, aerobic energy systems should be heavily taxed, which may decrease performance under such conditions.

Delimitations

Nine female soccer players between the ages 19 and 21 years were analyzed for this study. All participants were cleared by the institution for competition and played a minimum of sixty minutes in each game analyzed. Team activities were not augmented or changed in light of data collection and carried on with normal in-season protocols.

Limitations

1. The competition cannot be controlled, and thus no two competitions will be identical. The randomness of the activity profile across competitions exists, yet they should be individually similar.
2. Dietary and activity fluctuations may have occurred, which could impact performance.

Theoretical Assumptions

1. Subjects did not adjust or alter competition effort.
2. Subjects did not stray from normal nutritional intake prior or during competition.
3. No significant strategic changes were made during competition.
4. Pregame protocols were not altered.
5. Game readiness was the same across the competitions.

Statistical Assumptions

The population sample is normally distributed.

CHAPTER II

Literature review

Acute altitude exposure has been observed as a significant factor in decrements to performance through the impairment of the body's normal physiological function (B. Levine et al., 2008; Wehrlin & Hallén, 2006). To better understand the degree to which this impairment occurs upon ascension to various altitudes, studies have sought to investigate the acute effects of altitude exposure, as well as the necessary time tables for acclimatization (Aughey et al., 2013). Understanding the effects of acute altitude exposure is vital to understanding how individuals and teams accommodate to a change in the playing environment, and how to prepare for the competition.

In the sport of soccer, where high intensity running performance is crucial to maintaining game performance, hypoxia can present itself as a serious factor that impedes performance. Soccer is highly variable and unpredictable in terms of when exertions may be required or when high intensity runs are performed throughout the game (Krustrup et al., 2005; Mohr et al., 2003). Although acute altitude exposure has been shown to be a beneficial factor to brief high intensity running performances, one must consider the effects of acute exposure to altitude conditions on repeated sprints or high intensity runs (Arsac, 2002; Ferlic et al., 2007). While research directly assessing high intensity running in soccer performance upon acute altitude exposure is limited, several studies have observed the impact of acute altitude exposure on sprinting and endurance running performance (Arsac, 2002; Wehrlin & Hallén, 2006).

When considering the impact of acute moderate altitude exposure on high intensity running performance in athletes, the individual's rest interval and metabolic cost must be considered. In conjunction with individual bouts of high intensity running, an elite soccer game involves a substantial aerobic component which will in turn impact the metabolic demands of an athlete (B. Levine et al., 2008). With this understanding, it is important to recognize how altitude impacts both individual bouts of high intensity running performance and aerobic running performance, as well as the role of rest and recovery on these performance measures.

High Intensity Running at Altitude

Research examining high intensity running performance at altitudes of 1,800 meters above sea level are limited, with limited studies examining acute exposure to such conditions in runners. Historically, athletic events requiring acute speed and jumping have been shown to excel at altitude, This was first highlighted during the 1968 Mexico Olympics in the track and field events. Before this time, little attention was given to the environmental effects of competition at altitude. Since this event, more attention was given to competitions held at moderate to high altitudes (altitude > 2000m), and has gained the attention of international athletic associations such as FIFA (Bärtsch et al., 2008).

In several studies examining high intensity running performance at altitude, investigators did not detect any deleterious effects during a single high intensity performance that would not be present in normal conditions (Coudert, 1992; Ogawa et al., 2005; Ogawa, Hayashi, Ichinose, Wada, & Nishiyasu, 2007). Ferliche et al. (2007) investigated the impact of moderate altitude (2,320 m) on 400m sprint performance with different rest intervals (1 min, 2 min, 5 min).

Investigators found no significance in accumulated oxygen deficit (AOD) across the trials, indicating that acute hypoxia does not inhibit anaerobic metabolism. These results have been confirmed by other studies (McLellan, Kavanagh, & Jacobs, 1990; Ogawa et al., 2007). McLellan et al (1990) found that although aerobic capacity was inhibited, performance was not impaired during trials of 30 and 45 seconds of supramaximal exercise. To corroborate the findings of McLellan et al. in high intensity runners, Ogawa et al. (2007) found in competitive distance runners performing intermittent graded sprints that performance was not inhibited due to compensatory increase in anaerobic metabolism.

Metabolic Demands of High Intensity Running

Studies have shown that during the glycolytic energy systems is capable of compensating for the lack of available oxygen during short duration, high intensity exertion (McLellan et al., 1990). This overcompensation by the anaerobic energy systems begins to fade as the body begins to deplete anaerobic energy substrates and becomes more dependent on oxygen for aerobic metabolism (Balsom, Gaitanos, Ekblom, & Sjödín, 1994; McLellan et al., 1990; Ogawa et al., 2005). Feriche et al. (2007) observed a decline in performance when participant were given shorter rest intervals, as opposed to improvements in performance when provided more time to recover.

Although research has demonstrated that anaerobic metabolism is capable of compensating for the lack of aerobic contribution during repeated bouts of high intensity running, some decrements in performance have been observed as anaerobic energy substrates are exhausted (Balsom et al., 1994). In contrast, some studies have seen no impairment in

performance under hypoxic conditions, observing little to no difference between normoxic and hypoxic trials at moderate to high (2,500-5,200 m) altitude conditions (Coudert, 1992; Ogawa et al., 2007). Investigators have noted, however, that the lower availability of oxygen in a hypoxic environment resulted in a greater accumulation of lactate in the blood following intermittent high intensity exercise. Balsom et al. (1994) attributed the impairments in performance to the accumulation of blood lactate and lower oxygen uptake, impairing aerobic metabolism and the body's ability to sustain a higher power output.

For all the studies previously mentioned that performed a graded exercise test, a decline in VO_{2max} during high intensity exercise was observed upon exposure to moderate to high altitude conditions. In conjunction with the findings of Balsom et al (1994) and many others, the decline in oxygen availability impacts the body's metabolic response during energy production. Sojourns to altitude increase reliance on the glycolytic energy system (McLellan et al., 1990). Aside from the repeated sprint trials, Wehrin and colleagues (2006) found a linear decrease in VO_{2max} from low to moderate (300-2,800 m) altitudes in endurance runners. He also found a decrease in performance across the trials in time to exhaustion, with a mean decrease of 14.3% (range: 10.3-18.1%).

High Intensity Running and Field Sports

In light of these findings, an elite soccer game is lengthy in comparison to most study trials, and unpredictable in terms of the timing and duration of high intensity bouts. The athletic demands of a game require the use of many aerobic and anaerobic movements, with the most predominant of these movements being the running aspect of the sport (Krustrup et al., 2005).

The duration of a game requires these athletes to be well conditioned in order to maintain a high level of skilled performance (Bradley et al., 2009; Mohr et al., 2003). In regards to the sport of soccer, the nature of the game involves numerous bouts of high intensity running covering various distances (Bradley et al., 2009; Krustup et al., 2005). Although the demands and characteristics of each game are different, each game incorporates these components and requires athletes to be both aerobically and anaerobically conditioned.

A game of soccer is 90 minutes in duration. To better understand the game, investigators have incorporated the use of technology to break down the activity sequence of athletes to quantify physical exertions and movements in an active game (Aughey, 2011). Evaluating and analyzing live games has shown to be useful to many elite level teams, as high intensity running has shown itself to be a valid measure of physical performance in the sport of soccer (Mohr et al., 2003). Through evaluating the game itself, one can acquire performance level activity of individuals without having to replicate or simulate game scenarios.

Krustup and colleagues (2005) performed an analysis of 14 elite female soccer players across 4 matches, and found that during a match, a mean distance of 10.3 kilometers (km) was run, and 1.31 km (125 efforts) of that distance was performed at a high intensity ($>15 \text{ km}\cdot\text{hr}^{-1}$) of movement. The remainder of the time was spent at lower intensities of activity while still in the field of play ($<15 \text{ km}\cdot\text{hr}^{-1}$). Some investigators have noted some minor differences between players in different positions on the field, yet found that differences in the distance covered throughout the match and distance covered at a high intensity were reflective of a player's position and the tactical demands associated with it (Mohr et al., 2003). Regardless of player

position, high intensity runs appear to require a high level of aerobic fitness in the game of soccer (McCormack et al., 2013).

In further analysis of the metabolic demands of elite female soccer players, McCormack et al. (2013) observed power output in female soccer players and its relationship to high intensity running speed and the frequency of exertions. Investigators found power output to be critical to high intensity running performance, primarily regarding running speed, supporting the stance that soccer requires substantial anaerobic contribution. Such evidence suggests that at an elite level, power output may become increasingly important to sustain performance at a higher level. Coinciding with the importance of power production to performance, McCormack et al. noted that sustained high intensity running performance is associated to VO_{2max} , demonstrating the need for substantial aerobic capacity in sustained competition. In terms of the relationship between VO_{2max} and power output, investigators noted an inverse relationship, suggesting that aerobic capacity may have a limited role in anaerobic activity. With this understanding, one must consider events where bouts are repetitive. Associations observed between high intensity running and VO_{2max} suggest that aerobic capacity may be an important factor to sustaining high intensity running performance. Its impact on recovery has been observed by Hoffman et al. (1997), suggesting that it may play a critical role in recovery following bouts of high intensity running.

Considering the profile of an elite game, studies have shown that physiological capacity is indicative of the performance level of soccer players (Krustrup et al., 2005; Mohr et al., 2003). Krustrup and colleagues (2005) observed that an athlete's activity profile during competition was

adjusted based on their physiological capacity, with performance reflecting measures obtained prior to competition. When observing heart rates in matched female soccer players throughout competition conjunction with performance data, they found that players with greater physical capacity were exerting themselves just as much as those with lesser physical capacity. This model is also reflective in studies of elite male soccer players as well, with greater physical capacity observed in players of a higher level of performance (Bradley et al., 2009; Mohr et al., 2003). These findings suggest that despite physical capacity of the athlete, he or she will exert themselves to a high degree to perform within their ability.

In conjunction with the findings of Krustup et al. (2005), Bishop et al. (2006) observed high intensity running performance in field sport athletes, and found that in individuals matched for initial sprint performance, aerobic capacity was associated with repeated sprint performance. Higher trained individuals, although fatiguing along the same pattern as the lesser trained participants, performed more work at the conclusion of the trial. These findings also corroborate the findings of Bradley et al (2009) and Krustup et al (2005) in terms of the differences observed in the level of play between athletes and their respective physiological capacity. The main assumption that can be derived from such a relationship between aerobic capacity and high intensity performance is that despite the predominant anaerobic nature of high intensity running, in field sports, individual aerobic capacity is a determining factor in sustained high intensity running performance.

Understanding that aerobic capacity is an important factor in game performance, and that players appear to exert themselves relative to their own ability, several studies investigating elite

soccer performance in competition have demonstrated that there is a marked decrease in high intensity running performance towards the conclusion of a game (Krustrup et al., 2005; Mohr et al., 2003). Krustrup et al (2005) observed a decrease of 30% and 34% in distance covered between the first and last 15 minutes of the first and second halves, respectively. Mohr et al (2003) performed a similar analysis with elite male soccer players and observed a similar decline in high intensity running towards the end of the competition. Although every game will be different in regards to the timing and duration of high intensity and lower intensity bouts of exercise, patterns observed by investigators indicate that the rate of fatigue is fairly consistent between games (Bradley et al., 2009; Mohr et al., 2003). As was previously discussed, both physical capacity and player position have been shown to be factors in overall performance. In spite of these findings, and in conjunction with what has been observed in player exertion, the rate of fatigue between players has been found to be consistent regardless of player position or level of play (Bradley et al., 2009).

Soccer Performance at Altitude

Studies directly analyzing soccer performance at altitude are very limited, with a majority of the literature examining the outcomes of games in retrospective analysis. McSharry (2007) performed an analysis of 1460 games played in South America over a century, analyzing the outcomes of 10 national teams of both home and away games. He found that teams native to high altitude playing at altitude scored more and allowed fewer goals when playing a home game against a team that resided at sea level, and that the probability of a win increased by nearly 30%. Understanding that such an advantage may exist for the home team competing in altitude conditions, FIFA imposed a ban on matches performed over 2,500 meters. The following year,

after great political outcry from several South American countries, FIFA suspended the ban and released a consensus statement outlining the effects of altitude on human physiological function and ways for teams to better prepare for competition in such conditions (Bärtsch et al., 2008). It is apparent that competing in altitude conditions is recognized as a disadvantage when acclimatization is not allowed to occur.

Considering the disadvantage that appears to exist for teams residing at sea level to compete at altitude against altitude native teams, research should examine whether performance markers significantly change when ascending to altitude to compete. Observing markers in performance within the competition itself removes any conflicts of the transferability of the findings. High intensity running has been shown to be a factor predictive of performance among elite soccer players, and thus would be a marker of inhibited performance. Observing the overall rate of a game would demonstrate inhibitory changes as well if the effect is deleterious. Both the rates of high intensity running and the total distance covered have been associated with VO_{2max} , which has shown to be negatively affected by altitude exposure. Observing these aspects in competition, which are crucial to athlete performance in the game of soccer, would demonstrate if deviations in such critical performance measures exist at a moderate altitude.

CHAPTER III

Methodology

Experimental Design

Three Division I women's soccer competitions were retrospectively analyzed to assess high intensity running performance throughout the duration of a competitive soccer game. Two competitions performed at sea level (Orlando, FL; 25 m) were averaged to establish a baseline performance measure, followed by a competition in Colorado Springs, Colorado (1840 m), which was considered to be the game performed at altitude. During all competitions players wore global position devices (GPS) Deidentified data was analyzed for the both the rates of high intensity running (HIR) and total distance covered (TDC), and comparisons were made between games played at sea level and at altitude (see Table 1.). All games played were classified as close games, which was operationally defined as the outcome being within 2 goals.

There was a significant difference in the number of minutes played between the games ($p = 0.003$, -11 ± 4.8 min). To account for differences in time played during competition, a baseline threshold of sixty minutes was implemented ensure that players' activity during a game was substantial. Following this exclusion factor, data from six players was used in retrospective analysis. Understanding that there was a significant difference in minutes played, measures of distance and time were excluded due to the direct correlation with time spent on the field.

Table 1: Competition Descriptives

	Time (EDT)	Temp.	Conditions	Humidity	Pressure	Wind Speed	Altitude
Sea Level	6:53 PM	81 °F	Mostly Cloudy	72%	30.00 in	9.2 mph	
	7:53 PM	80 °F	Clear	79%	30.01 in	8.1 mph	25 m
	8:53 PM	79 °F	Overcast	79%	30.02 in	6.9 mph	
Sea Level	6:53 PM	77 °F	Clear	94%	30.01 in	Calm	
	7:53 PM	78 °F	Clear	90%	30.02 in	Calm	25 m
	8:53 PM	78 °F	Clear	87%	30.04 in	3.5 mph	
Altitude	6:54 PM	48 °F	Scattered Clouds	83%	29.99 in	4.6 mph	
	7:54 PM	48 °F	Scattered Clouds	87%	30.00 in	Calm	1840 m
	8:54 PM	46 °F	Scattered Clouds	86%	29.97 in	5.8 mph	

Participants

Retrospective examination of six National Collegiate Athletic Association (NCAA) Division I women soccer players (19.5 ± 1.0 y; 165.2 ± 5.5 cm; 62.1 ± 6.4 kg) was performed. The athletes' playing positions consisted of defenders (2), midfielders (2), and forwards (2). Games analyzed were performed during three consecutive weeks. Each game was performed on a Friday evening and was separated by five days from their previous competition. All performance assessments were part of the athletes' regular in-season assessment protocol that was designed to provide feedback to the coaching staff regarding player progress or fatigue. All players had passed the team's mandatory pre-participation physical prior to the onset of the season. The players gave their informed consent as part of their sport requirements, which is consistent with our institution's policies for use of human participants research.

Game Data Collection

Prior to every competition, each athlete was fitted with a 10-Hz GPS receiver/transmitter (Catapult, Minimax 4.0, Victoria, Australia) that was placed in a pocket of a vest worn under their game jersey during competition. The pocket was located between the athlete's shoulder blades. Competitions took place on a Friday at 7:00 PM EST when in Orlando, FL and 5:00 PM MST when in Colorado Springs, Colorado. The coaches followed their normal game routines, with no interventions performed to compensate for altitude change. Post-competition, data collected by the GPS receivers/transmitters was downloaded for analysis using Catapult Sprint Software.

Velocity Zones

Analysis of the raw data files was performed post-competition, and was saved to derive individual athlete reports. Each athlete's physical activity was monitored on the field and defined across various thresholds (bands), with parameters set for each band (Labeled I-VII) (see Table 2). Within each band, each athlete's activity was measured by the time spent within that band width, the number of events at that threshold, and the percentage of the game that took place in each band. HIR was defined to include moderate and high speed running and sprinting (bands V through VII). Within the bands, percentage of time and rate of HIR and rate of TDC during each half were assessed to observe patterns in HIR performance and rates of fatigue during the games.

Table 2: Velocity Zones

Classification	Band	Low (m/s)		High (m/s)	Label
Rest/ Recovery	I	0.00	-	0.56	Standing
	II	0.56	-	1.94	Walking
	III	1.94	-	2.50	Jogging
	IV	2.50	-	3.61	Low Intensity Running
	V	3.61	-	4.44	Moderate Intensity Running
HIR	VI	4.44	-	6.11	High Intensity Running
	VII	6.11	>		Sprinting

Statistical Analysis

The impact of altitude on player performance was calculated as the change in performance from sea level to altitude performance. A paired sample t test was performed to determine if there was a difference in mean rate of HIR and TDC, as well as the percentage of time of HIR at altitude compared to the mean rate of HIR at sea level in competition. An alpha level of 0.05 was used.

CHAPTER IV

Results

The relative distance covered in a game ($\text{m}\cdot\text{min}^{-1}$ played) can be observed in Figure 1. Participants playing at altitude appeared to cover a significantly ($p = 0.000$) reduced distance per minute ($105.8 \pm 10.2 \text{ m}\cdot\text{min}^{-1}$) compared to when they played at sea level ($120.6 \pm 8.3 \text{ m}\cdot\text{min}^{-1}$). Distance per minute was significantly different in the first half ($p = 0.006$), with the rate at altitude being significantly less ($109.6 \pm 8.6 \text{ m}\cdot\text{min}^{-1}$) than at sea level ($123.1 \pm 7.8 \text{ m}\cdot\text{min}^{-1}$). In the second half, distance per minute was also found to be significant ($p = 0.003$), with the rate at altitude being significantly less ($105.9 \pm 7.1 \text{ m}\cdot\text{min}^{-1}$) than at sea level ($119.4 \pm 8.2 \text{ m}\cdot\text{min}^{-1}$).

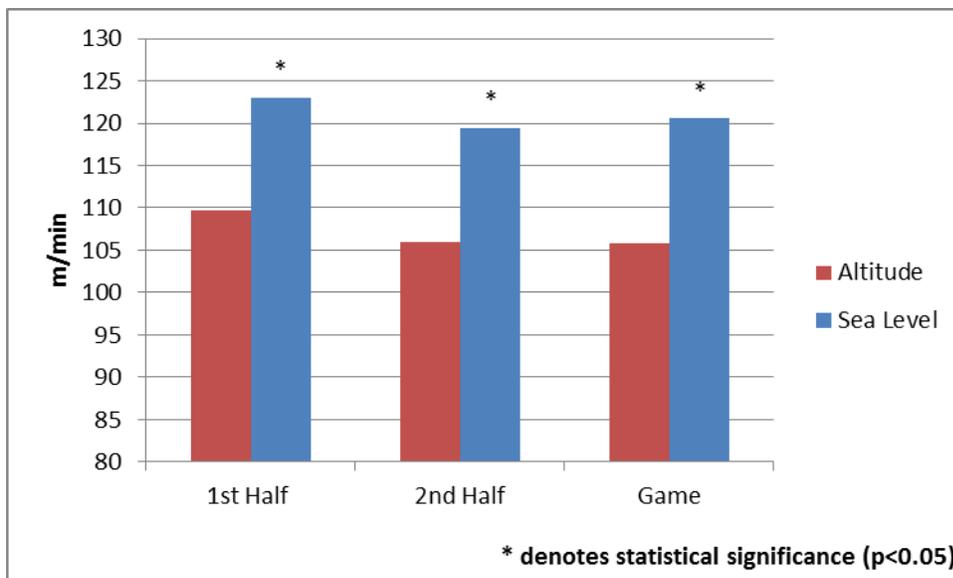


Figure 1: Rate of Total Distance Covered

Comparison in high intensity runs can be observed in Figure 2. During the first half the distance covered during the high intensity runs were significantly lower ($p = 0.022$) at altitude

($25.0 \pm 9.0 \text{ m}\cdot\text{min}^{-1}$) than observed at sea level ($27.9 \pm 9.4 \text{ m}\cdot\text{min}^{-1}$). No difference ($p = 0.288$) was seen in the distance covered during the high intensity runs in the second half of the contests ($25.1 \pm 6.6 \text{ m}\cdot\text{min}^{-1}$ versus $27.5 \pm 9.3 \text{ m}\cdot\text{min}^{-1}$ during altitude and sea level, respectively). However, when distance covered during high intensity runs for the games was calculated, participants playing at altitude covered significantly ($p = 0.037$) less distance ($25.1 \pm 7.7 \text{ m}\cdot\text{min}^{-1}$) than when playing at sea level ($27.7 \pm 9.2 \text{ m}\cdot\text{min}^{-1}$).

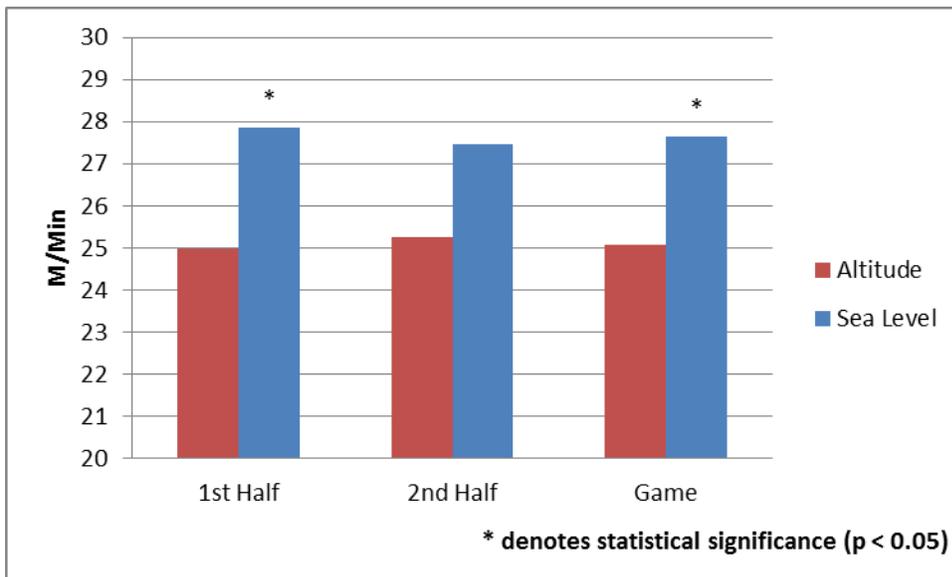


Figure 2: Rate of High Intensity Running

Figure 3 depicts the percent time spent at high intensity running. A significant difference ($p = 0.039$) was seen in the first half between the games played at altitude ($9.0 \pm 2.2\%$) compared to sea level ($10.3 \pm 3.2\%$), but no difference between the games was seen ($p = 0.23$) in the second half of each contest. When comparing the percent time spent at high intensity runs for the entire game, participants performed high intensity runs for $10.4 \pm 3.3\%$ of

the game at sea level which tended to be greater ($p = 0.064$) than when they performed at altitude ($9.1 \pm 2.2\%$).

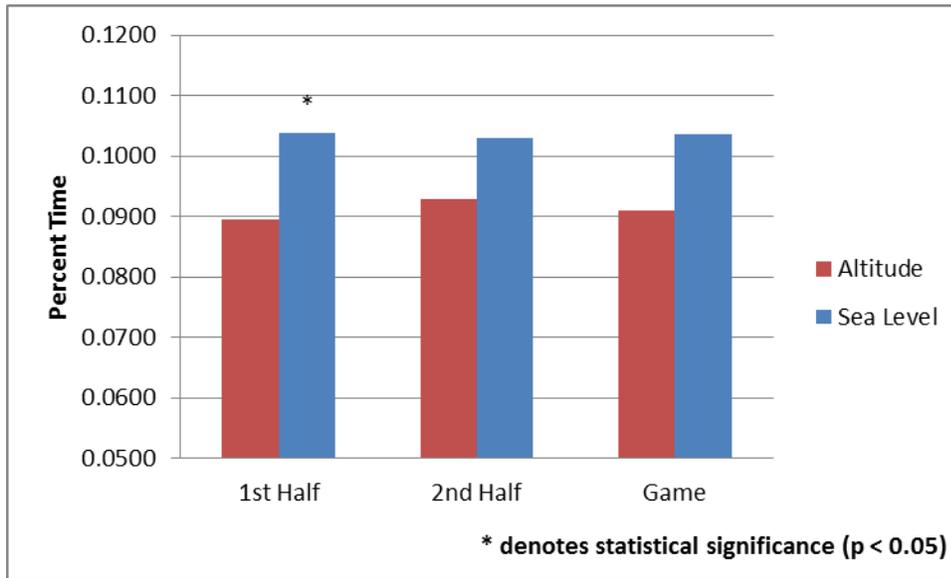


Figure 3: Percent Time at High Intensity Running

CHAPTER V

Discussion

The main findings of this study suggest that players who reside at sea level and travel to a competition at a moderate altitude (1800 m) may be at a competitive disadvantage. This is based upon significant decreases observed in the total distance covered, expressed as meters per minute played, and the distance covered during high intensity runs, for the duration of the game performed at altitude compared to the average performance seen during competitions at sea level. These effects were consistent in both the first and second halves of the game. Although this appears to be the first investigation to compare performance variables in contests occurring at both sea level and at a moderate altitude, it does appear to support a previous study suggesting that teams residing at sea level are at a competitive disadvantage when they play at altitude (McSharry, 2007). In that study, which examined the outcomes of 10 national teams in South America (a total of 1460 games) the investigator reported that teams native to high altitude and playing at altitude had nearly a 30% greater probability of winning in home games played at altitude competing against opponents that resided at sea level. Although the FIFA considered a ban on matches performed over 2,500 meters, they did suggest that teams better prepare for games played at altitude through appropriate acclimatization (Bärtsch et al., 2008). However, for intercollegiate competitions the opportunity for athletes to acclimate to altitude is very limited considering that multiple games are played weekly.

Previous studies examining high intensity exercise performance at altitude are very limited. Niess and colleagues (2003) reported that the acute stress response during high intensity

interval training in endurance athletes was more pronounced at a moderate altitude (1800 m) than at sea level. Friedman and colleagues (2007) suggested that anaerobic capacity is not significantly changed during acute exposure to moderate hypoxia in endurance-trained athletes however the reduction in time to exhaustion during the maximal effort bout of exercise of short duration was attributed to the decrement in aerobic capacity. Clark and colleagues (2007) examining triathletes performing 5-min time trials that preceded a bout of interval exercise at various altitudes indicated a dose-response effect on high intensity performance, suggesting that at higher altitudes (within the 2000 – 3200 m altitude range) the ability to maintain performance was impaired. In contrast, Ferliche et al. (2007) investigated the impact of a moderate altitude (2320 m) on repeat 400m sprint performance with different rest intervals (1 min, 2 min, 5 min) and found no significant difference in accumulated oxygen deficit across the trials, suggesting that acute hypoxia did not inhibit anaerobic metabolism. Although the majority of these studies suggest a greater risk for performance decrements and fatigue during exercise at a moderate altitude, none of these studies examined a protocol that simulated actual sport performance.

One study attempted to simulate rugby performance at 1550 m (Hamlin, Hinckson, Wood, & Hopkins, 2008). They reported significant decrements in repetitive explosive power (approximately -16%) and 20-m shuttle performance (approximately -3%) decreased substantially at altitude compared to sea level. Recently, Goods et al., (2014) examined male team sport athletes performing three sets of repeated sprints (9 x 4 sec) on a non-motorized treadmill at simulated altitude (2000m, 3000m and 4000m) and reported that mean power output was reduced at all moderate altitudes and lactate concentrations were significantly greater at all altitudes compared to sea level. Our findings provide additional support to these investigations

indicating the deleterious effects of performing at altitude. This present study though appears to be the first to examine actual game performance.

The significant declines in total distance covered and in distance of high intensity runs during a soccer game at a moderate altitude may be attributed to both a decrease in aerobic capacity and a decline in anaerobic power capacity in these athletes. In studies examining soccer athletes, both aerobic capacity and high intensity running performance were demonstrated to be predictive of game performance, and associated with level of play (Bradley et al., 2009; Krstrup et al., 2005; Mohr et al., 2003). In a study examining NCAA Division I female soccer players, high intensity runs appear were associated with a high level of aerobic fitness (McCormack et al., 2013). Interestingly, those investigators indicated that power output in female soccer players was related to high intensity running speed and the frequency of high intensity exertions on the field. Investigators found power output to be critical to high intensity running performance, primarily regarding running speed, supporting the stance that soccer requires substantial anaerobic contribution. McCormack and colleagues (2013) also noted that sustained high intensity running performance was associated with VO_{2max} , demonstrating the need for substantial aerobic capacity during a sustained soccer competition. Although aerobic capacity likely has a limited role in anaerobic activity, previous research has suggested that it may play a critical role in recovery following bouts of high intensity running (Hoffman, 1997). Therefore, during a soccer game performed at a moderate altitude the ability to recover from high intensity runs may be reduced. The results of this present study do appear to support that hypothesis.

Conclusions

In conclusion, the results of this study indicate that non-acclimatized soccer players performing at a moderate altitude may experience declines in total distance run, and their ability to sustain higher rates of running for the duration of the game. This may result in a potential competitive disadvantage for athletes that reside at sea level and travel to play at moderate altitudes. Future research should focus on potential countermeasures to minimize this competitive disadvantage.

APPENDIX: UCF IRB APPROVAL LETTER



University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901, 407-882-2012 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

NOT HUMAN RESEARCH DETERMINATION

From : **UCF Institutional Review Board #1
FWA00000351, IRB00001138**

To : **William P. McCormack**

Date : **December 13, 2012**

Dear Researcher:

On 12/13/2012 the IRB determined that the following proposed activity is not human research as defined by DHHS regulations at 45 CFR 46 or FDA regulations at 21 CFR 50/56:

Type of Review: Not Human Research Determination
Project Title: TRACKING MEASURES OF POWER AND
COGNITIVE FUNCTION ACROSS A SOCCER
SEASON IN COLLEGIATE WOMEN SOCCER
PLAYERS
Investigator: William P. McCormack
IRB ID: SBE-12-08863
Funding Agency:
Grant Title:
Research ID: N/A

University of Central Florida IRB review and approval is not required. This determination applies only to the activities described in the IRB submission and does not apply should any changes be made. If changes are to be made and there are questions about whether these activities are research involving human subjects, please contact the IRB office to discuss the proposed changes.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 12/13/2012 04:22:03 PM EST

A handwritten signature in black ink, appearing to read "Patria Davis".

IRB Coordinator

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