THE EFFECTS OF PLYOMETRIC TRAINING IN NORMOBARIC HYPOXIA ON BODY COMPOSITION, ANAEROBIC PERFORMANCE, STRENGTH AND EXPLOSIVE POWER

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

THE EFFECTS OF PLYOMETRIC TRAINING IN NORMOBARIC HYPOXIA ON BODY COMPOSITION, ANAEROBIC PERFORMANCE, STRENGTH, AND EXPLOSIVE POWER

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Purpose of this study is comparing the effects of plyometric training in hypoxia and normoxia on body composition, jump and sprint performance, Wingate anaerobic power and isokinetic strength test results. 23 male volunteers from physical education students (Age=20.39±2.02) participated and were randomly divided into Plyometric training in Hypoxia (PTH)(n=8), Plyometric training in Normoxia (PTN)(n=7) and Control (n=8) groups. While PTH performed plyometric training under normobaric hypoxic conditions (3.536m) with using a face mask attached to a portable hypoxic generator 3 days/week for 8 weeks, PTN performed the same training in normoxic condition. While significant differences were found in Countermovement-jump (14.80%), Squat-jump (16.06%), Drop-jump height (15.97%), Drop-jump contact-time (5.36%), Reactive-Strength-Index (10%) and Sprint (3.42%) in PTH, only variables of Countermovement-jump (8.55%) and Sprint (2.58%) were found to be significant in PTN. According to Wingate results, significant increase was found in peak power both in PTH by

60.53W (7.72%) and PTN by 46.14W (6.09%), and in relative peak power both in PTH by 0.89W/kg (7.89%) and in PTN by 0.81W/kg (7.05%). Only PTH presented a significant increase in Flex.maxTorque (15.69%) and Flex.Peak Power (18%) of right leg at the speed of 60°/sec, and in Flex.Peak Power of right leg (12.30%) at the speed of 180°/sec ($p<0,05$). Non-significant difference in body composition but greater improvements in strength, sprint and jump in PTH suggests improvements were resulting from neural adaptation rather than hypertrophy. It can be concluded normobaric hypoxia is effective for performance improvement especially in explosive activities, most likely based on neural contribution.

Keywords: Plyometric training in normobaric hypoxia (PTH), Plyometric training in normoxia (PTN), Anaerobic performance, Strength, Explosive power.

ÖZ

NORMOBARİK HİPOKSİDE UYGULANAN PLİOMETRİ ANTRENMANIN VÜCUT KOMPOZİSYONU, ANAEROBİK PERFORMANS, KUVVET VE PATLAYICI GÜÇ ÜZERİNE ETKİLERİ

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Bu çalışmanın amacı, hipoksi ve normoksideki pliometri antrenmanın vücut kompozisyonu, sıçrama ve sprint performansı, Wingate anaerobik güç testi ve izokinetik kuvvet testi sonuçları üzerindeki etkilerini karşılaştırmaktır. Çalışmada, 23 erkek beden eğitimi öğrencisi (Yaş = 20.39 ± 2.02) gönüllü olarak yer almıştır, ve PTH (hipokside pliometri antrenmanı) grubu (n = 8), PTN (normokside pliometri antrenmanı) grubu (n = 7) ve Kontrol grubu (n = 8) olmak üzere 3 gruba rastgele yöntemle ayrılmıştır. PTH grubu, pliometri antrenmanını, portatif hipoksik jeneratöre (Everest Summit II, Hypoxia, NY, ABD) bağlı bir yüz maskesi ile normobarik hipoksik ortam sağlanarak (3.536 m) 8 hafta boyunca haftada 3 gün uygularken, PTN grubu aynı antrenman programını normoksi ortamda uyguladı. PTH grubunda Countermovement-jump (aktif-sıçrama) (14.80%), Squat-jump (squat-sıçrama) (16.06%), Drop-jump (düşerek-sıçrama) yüksekliği (15.97%), düşerek-sıçrama yerle temas süresi (5.36%), Reaktif kuvvet indeksi (10%) ve

Sprint (3.42%) değerlerinde anlamlı farklılık bulunurken, PTN grubunda sadece Countermovement-jump (8.55%) ve Sprint (2.58%) değerleri anlamlı bulunmuştur. Wingate sonuçlarına göre, maksimum güç (PTH’de 60.53W (7.72%), PTN’de 46.14W (6.09%)) ve rölatif maksimum güç (PTH’de 0.89W/kg (7.89%), PTN’de 0.81W/kg (7.05%)) değerlerinde hem PTH hem de PTN grubunda anlamlı artış bulunmuştur. Sağ bacakta, 60°/sn hızda Fleks.maxTork (15.69%) ve Fleks. maksimum güç (18%) değerinde ve 180°/sn hızda Fleks. maksimum güç (12.30%) değerinde sadece PTH grubu anlamlı artış göstermiştir ($p<0,05$). Vücut kompozisyonunda anlamlı fark bulunmazken, kuvvet, sprint ve sıçrama değerlerinde PTH grubunda daha yüksek gelişim bulunması, bu gelişmelerin hipertrofiden ziyade nöral adaptasyondan kaynaklandığını desteklemektedir. Normobarik hipoksinin, özellikle patlayıcı aktivitelerde, büyük olasılıkla nöral katkıdan kaynaklı bir performans gelişiminde etkili olduğu sonucuna varılabilir.

Anahtar Kelimeler: Normobarik hipokside pliometri antrenmanı, Normokside pliometri antrenmanı, Anaerobik performans, Kuvvet, Patlayıcı güç.

To my dear father

who I still feel next to me and he will always there

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LIST OF ABBREVIATIONS

1RM	One Repetition Maximum
ATP	Adenosine Triphosphate
BFM	Body Fat Mass
BFP	Body Fat Percentage
BFR	Blood Flow Restriction
BMI	Body Mass Index
BW	Body Weight
CHT	Continuous Hypoxic Training
CMJ	Countermovement Jump
CNS	Central Nervous System
CO_2	Carbon dioxide
DJ	Drop Jump
EPO	Erythropoietin
Ext. maxTorque	Extension Maximum Torque
Flex. maxTorque	Flexion Maximum Torque
Flex./ext	Flexion/ Extension
FT	Fast-Twitch
GTO	Golgi Tendon Organ
IHRT	Intermittent Hypoxic Resistance Training
IHT	Intermittent/Interval Hypoxic Training
IPC	Ischemic Preconditioning
LBM	Lean Body Mass
LHTH	Live High-Train High
LHTL	Live High-Train Low
LLTH	Live Low-Train High
Min. Power	Minimum Power
N_2	Nitrogen

O_2	Oxygen
Pi	Inorganic Phosphate
PO_2	Partial Pressure of Oxygen
PTH	Plyometric Training in Hypoxia
PTN	Plyometric in Normoxia
RBC	Red Blood Cell
Rpm	Revolution per Minute
RSA	Repeated Sprint Ability
RSH	Repeated Sprint Training in Hypoxia
RSI	Reactive Strength Index
RSN	Repeated Sprint Training in Normoxia
RTH	Resistance Training in Hypoxia
SEC	Series Elastic Component
Sec	Second
SJ	Squat Jump
SO_2	Oxygen Saturation
SQAT	Strength Qualities Assessment Test
SSC	Stretch-Shortening Cycle
ST	Slow-Twitch
VJH	Vertical Jump Height

CHAPTER 1

INTRODUCTION

So many types of altitude training are used by elite athletes around the world (Lundby & Robach, 2016) and become increasingly prevalent for performance improvement at sea level (Álvarez-Herms, Julià-Sánchez, Corbi, Pagès, & Viscor, 2014). It is stated that the stress of hypoxia in addition to training enhances the training adaptations and produces greater improvements in performance (Morton & Cable, 2005). The reason is that altitude hypoxia is also a stress factor which provides physiological changes, such as improvements in total blood volume, hemoglobin, red blood cell count, mitochondrial concentration and muscle enzyme changes, similar to the ones provided by physical training (Fox, Bowers, & Foss, 1988).

Typically, the ascent to a high altitude is regarded as related to impaired endurance performance, but staying at altitude makes some beneficial changes connected with aerobic energy system by providing chronic adaptations and improves performance (Feriche, García-Ramos, Morales-Artacho, & Padial, 2017). To gain a competitive advantage, many of elite endurance athletes regularly stay at high altitude or perform hypoxic training with different methods (Brocherie, Girard, Faiss, & Millet, 2017). However, it is stated that short-term activities based on non-oxidative metabolism appear to offer rapid benefits when applied under altitude conditions, as well (Feriche et al., 2017).

By now, most commonly, athletes have preferred to live and do training at high altitude (Live High-Train High, LHTH), or to live at high altitude and do exercise at sea level (Live High-Train Low, LHTL), as a hypoxic training (McLean et al., 2014; Faiss, Girard, & Millet, 2013). However, the dose of hypoxia, which provides the physiological advantage in the techniques of Live High-Train High (LHTH) or Live High-Train Low (LHTL), requires partially prolonged exposure (at least 2 weeks / more than 12 hours per day) (McLean et al., 2014).

Therefore, alternative training techniques in hypoxia such as Live Low-Train High (LLTH) have gained importance (Brocherie et al., 2017; McLean et al., 2014). The underlying rationale for LLTH comes from the idea of providing greater skeletal muscle adaptations than identical training in normoxic conditions (Lundby & Robach, 2016). In this method, athletes live in normoxic conditions and perform training sessions under hypoxic conditions (McLean et al., 2014). The hypoxic exposures in this technique usually last shorter than 3 h and nearly 2-5 times per week, thereby, do not supply a sufficient hypoxic stimulus to result in hematological changes in association with the LHTH and LHTL methods (McLean et al., 2014).

Also, the benefits of this method to improve sea level performance are more evident in anaerobic efforts such as short-term high-intensity maximal intermittent exercises (Álvarez-Herms et al., 2014; McLean et al., 2014). Because of the decrease in aerobic ATP production in hypoxia, the energy requirement is widely provided by anaerobic sources for compensation in order to continue the same exercise intensity during all-out exercises (Álvarez-Herms, Julià-Sánchez, Gatterer, Viscor, & Burtscher, 2015).

One of the main training types within this model is Continuous Hypoxic Training (CHT). Because LLTH applications provide adaptation to mechanisms mostly related to anaerobic capacity, exercise intensities used in CHT are insufficient to provide an extra training benefit (McLean et al., 2014).

The second training type is Intermittent/Interval Hypoxic Training (IHT). While most studies on this type of training indicate that there is no additional benefit of hypoxia stimuli, a limited number of studies have been reported to provide further improvements when applied under certain conditions (McLean et al., 2014), and conflicting results regarding the effects are available (Faiss, Girard, & Millet, 2013; Girard, Brocherie et al., 2017).

The third training type is the Repeated Sprint Training in Hypoxia (RSH). Studies reported that this type of training increases mostly repeated sprint ability (Brocherie et al., 2017; Faiss, Léger, et al., 2013; Girard et al., 2017; McLean et al., 2014).

The fourth one is Resistance Training in Hypoxia (RTH). While the popularity of resistance exercises in normoxia conditions increased in the sports field, in the meantime, the interest on the extra effects of hypoxia stimulation increased and RTH emerged (Girard et al., 2017). However, there are few studies on this type of training and its effects are not exactly proven (Feriche et al., 2017; Girard et al., 2017; Inness et al., 2016; McLean et al., 2014).

Mostly these four training types have been mentioned among the LLTH training methods in systemic hypoxia in the literature, but pure plyometric training prescriptions were never seen to the best of our knowledge.

On the other hand, it has been proven that plyometric exercise improved muscle strength, power and speed in many studies up to now. Positive effects of plyometric exercise have been observed especially on jump performances in many sports (Slimani, Chamari, Miarka, Del Vecchio, & Chéour, 2016). It has been stated that plyometric training leads to specific neural adaptations like improvement of motor unit activation and less muscle hypertrophy than those achieved with heavy resistance strength training (Slimani et al., 2016). Moreover, it is possible to find combinations with various types of exercise (plyometric and strength, plyometric and aerobic, plyometric and flexibility, plyometric and electrostimulation, plyometric in water) (de Villarreal, Kellis, Kraemer, & Izquierdo, 2009), but it has not yet been combined with hypoxia. Therefore, the purpose of this study is to compare the effects of plyometric training in hypoxia and in normoxia on body composition, jump performance, sprint time, Wingate anaerobic power test and isokinetic strength test results in order to investigate the effects of plyometric training in hypoxia (PTH).

1.1. Significance of the Study

In the sport and exercise literature, ways of gaining a higher efficiency in exercise have been sought for years. This study seems promising about contributing to a bigger increase in efficiency than the same types of exercises done at the sea level, and it is the first of its kind to be applied in the literature. Although many training models in the field of hypoxic training have been applied so far, solely plyometric training hasn’t been tried under hypoxic conditions. When similar training programs under normoxic conditions, except for the plyometric training, are performed under hypoxic conditions, they may lead to a better physiological and muscular adaptation, thereby increasing efficiency in performance. Therefore, this study aimed at researching whether or not these effects on adaptation and performance will be manifested in plyometric exercises, as well.

Furthermore, due to the fact that muscle force or power development is not mostly evaluated in hypoxic conditions, there is a need for controlled and power-oriented resistance training researches in scientific reports in order to find out the effects of interval or prolonged hypoxia exposure on power training. It is stated that ascent to altitude induces speed and power developments but the mechanisms which are responsible for the hypoxia-induced improvements in normobaric hypoxia are not clear yet and need to be investigated (Feriche et al., 2017).

At the end of the study, if the plyometric exercises performed under hypoxic conditions are found to lead to a higher increase in performance than the plyometric exercises applied under normoxic conditions, then a new kind of hypoxic training will be added to the literature. Furthermore, for further studies, trying plyometric exercises under hypoxic conditions will be suggested for the athletes in many sports branches that require power, strength and anaerobic performance.

1.2. Research Question

What are the differences between the effects of plyometric hypoxia and normoxia training on body composition, jump variables, sprint test, Wingate anaerobic power test and isokinetic strength test?

Sub-questions

1. Does plyometric training in hypoxia and normoxia have a significant effect on body composition?
2. Does plyometric training in hypoxia and normoxia have a significant effect on the parameters of jump tests?
3. Does plyometric training in hypoxia and normoxia have a significant effect on sprint test result?
4. Does plyometric training in hypoxia and normoxia have a significant effect on the variables of the Wingate anaerobic power test?
5. Does plyometric training in hypoxia and normoxia have a significant effect on the variables of isokinetic strength tests?

1.3. Purpose of the Study

The purpose of this study is to compare the effects of plyometric training in hypoxia and in normoxia on body composition, jump performance, sprint time, Wingate anaerobic power test and isokinetic strength test results.

1.4. Research Hypothesis

1.4.1. Hypotheses Concerning Body Composition

H_0: There is no significant difference in body composition between pre and post-test results of hypoxia group.

H_1: There is a significant difference in body composition between pre and post-test results of hypoxia group.

H_0: There is no significant difference in body composition between pre and post-test results of normoxia group.

H_1: There is a significant difference in body composition between pre and post-test results of normoxia group.

H_0: There is no significant difference in body composition between pre and post-test results of control group.

H_1: There is a significant difference in body composition between pre and post-test results of control group.

H_0: There is no significant difference in body composition among the groups of hypoxia, normoxia and control.

H_1: There is a significant difference in body composition among the groups of hypoxia, normoxia and control.

1.4.2. Hypotheses Concerning Jump Variables

H_0: There is no significant difference in jump variables between pre and post-test results of hypoxia group.

H_1: There is a significant difference in jump variables between pre and post-test results of hypoxia group.

H_0: There is no significant difference in jump variables between pre and post-test results of normoxia group.

H_1: There is a significant difference in jump variables between pre and post-test results of normoxia group.

H_0: There is no significant difference in jump variables between pre and post-test results of control group.

H_1: There is a significant difference in jump variables between pre and post-test results of control group.

H_0: There is no significant difference in jump variables among the groups of hypoxia, normoxia and control.

H_1: There is a significant difference in jump variables among the groups of hypoxia, normoxia and control.

1.4.3. Hypotheses Concerning Sprint Test Result

H_0: There is no significant difference in sprint time between pre and post-test results of hypoxia group.

H_1: There is a significant difference in sprint time between pre and post-test results of hypoxia group.

H_0: There is no significant difference in sprint time between pre and post-test results of normoxia group.

H_1: There is a significant difference in sprint time between pre and post-test results of normoxia group.

H_0: There is no significant difference in sprint time between pre and post-test results of control group.

H_1: There is a significant difference in sprint time between pre and post-test results of control group.

H_0: There is no significant difference in sprint time among the groups of hypoxia, normoxia and control.

H_1: There is a significant difference in sprint time among the groups of hypoxia, normoxia and control.

1.4.4. Hypotheses Concerning Wingate Anaerobic Power Test Results

H_0: There is no significant difference in Wingate test variables between pre and post-test results of hypoxia group.

H_1: There is a significant difference in Wingate test variables between pre and post-test results of hypoxia group.

H_0: There is no significant difference in Wingate test variables between pre and post-test results of normoxia group.

H_1: There is a significant difference in Wingate test variables between pre and post-test results of normoxia group.

H_0: There is no significant difference in Wingate test variables between pre and post-test results of control group.

H_1: There is a significant difference in Wingate test variables between pre and post-test results of control group.

H_0: There is no significant difference in Wingate test variables among the groups of hypoxia, normoxia and control.

H_1: There is a significant difference in Wingate test variables among the groups of hypoxia, normoxia and control.

1.4.5. Hypotheses Concerning Isokinetic Strength Test Results

H_0: There is no significant difference in isokinetic strength variables between pre and post-test results of hypoxia group.

H_1: There is a significant difference in isokinetic strength variables between pre and post-test results of hypoxia group.

H_0: There is no significant difference in isokinetic strength variables between pre and post-test results of normoxia group.

H_1: There is a significant difference in isokinetic strength variables between pre and post-test results of normoxia group.

H_0: There is no significant difference in isokinetic strength variables between pre and post-test results of control group.

H_1: There is a significant difference in isokinetic strength variables between pre and post-test results of control group.

H_0: There is no significant difference in isokinetic strength variables among the groups of hypoxia, normoxia and control.

H_1: There is a significant difference in isokinetic strength variables among the groups of hypoxia, normoxia and control.

1.5. Limitations of the Study

1. The study was limited in application to male students from the Faculty of Sports Sciences who did not regularly perform physical activity at least 3 days a week except for their college curriculum at Ankara University.
2. A limited number of subjects participated.
3. The daily activities of the participants could not be controlled and they were assumed not to perform strength and plyometric training except for this study.

1.6. Assumptions

1. It is assumed that the subjects presented their best performance during the tests.
2. It is assumed that, throughout this research process, the subjects did not participate in any kind of plyometric and strength training except for the main training of this study.
3. It is assumed the subjects come to the training sessions without feeling tired.

CHAPTER 2

LITERATURE REVIEW

This chapter involves the literature review related to altitude training methods especially about the **Live Low-Train High** from three main altitude training models (live high + train high (LHTH), live high + train low (LHTL), and live low + train high (LLTH)).

Since no examples of plyometric training in hypoxia have been observed up to now, the methods with similar mechanisms, repeated sprint training in hypoxia and resistance training in hypoxia were tried to be explained and also an extra section was formed under the title of High intensity/explosive exercise in hypoxia. Besides, the other LLTH training methods were only briefly mentioned.

The chapter also involves information about plyometric exercise. What plyometric exercise is, how it works, its physiology, working mechanism, phases and factors affecting it were tried to be described, and some recommendations for plyometric training prescription were summarized.

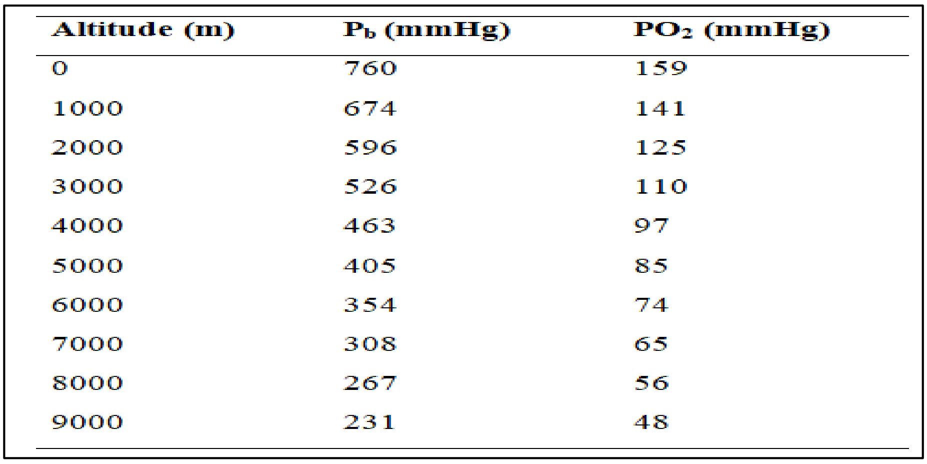
2.1. Altitude Training

Barometric pressure refers to the total pressure applied by all gases forming the atmosphere on the body or everything else and it is about 760 mmHg at sea level. Oxygen molecules compose of 20.93% of the air irrespective of barometric pressure (Kenney, Wilmore, & Costill, 2011). The partial pressure refers to the pressure of each gas (Hoffman, 2002) and the partial pressure of oxygen (PO_2) is 159 mmHg at sea level (Kenney et al., 2011). While the hypobaric environment refers to the decreased barometric pressure at altitude, hypoxia implies the low PO_2 in the air (Kenney et al., 2011).

Barometric pressure changes, but the percentages of gases in the air does not change from sea level to high altitude. Regardless of altitude level, the air consists of 20.93% oxygen, 0.03% carbon dioxide, and 79.04% nitrogen, but as long as the altitude increases, the partial pressure of these gases decreases (Hoffman, 2002; Kenney et al., 2011).

Table 2.1

Changes in Barometric Pressure and Partial Pressure of Oxygen at Varying Altitudes (Hoffman, 2002)



Altitude (m)	P_b (mmHg)	PO_2 (mmHg)
0	760	159
1000	674	141
2000	596	125
3000	526	110
4000	463	97
5000	405	85
6000	354	74
7000	308	65
8000	267	56
9000	231	48

2.1.1. Responses to Altitude

Altitude leads to a decreased PO_2 in the inspired air, alveoli, blood, and tissue. A range of adaptations arises for lessening the decline in oxygen delivery to the tissues, with acute exposure (Kenney et al., 2011).

Acute altitude exposure leads to a rise in pulmonary ventilation in order to compensate for oxygen deficit in tissues and organs (Wilber, 2004). Ventilation increases within seconds of altitude exposure owing to the low PO_2 and signals to the brain are transmitted in order to increase breathing (Kenney et al., 2011). Therefore, it is a quick response occurred within a few hours and becomes more notable during the first few days (Fox et al., 1988). It becomes stable approximately after a week at altitude (Fox et al., 1988; Vargas Pinilla, 2014).

Altitude exposure increases the heart rate at rest and submaximal exercise unlike maximal exercise in the first few days. A few hours exposure to altitude does not show considerable changes in stroke volume at rest or during exercise, but in two days it decreases notably and this decline may remain throughout several days at altitude (Wilber, 2004). While submaximal cardiac output increases (McArdle, Katch, & Katch, 2009), maximum cardiac output does not change or decreases slightly (McArdle et al., 2009) due to the decreasing stroke volume and heart rate during the maximal exercise, but over the several weeks, maximal cardiac output increases because of the acclimatization (Kenney et al., 2011).

The prevalence of the altitude training for aerobic performance enhancement is because of the fact that the decrease in PO_2 stimulates the EPO release. Serum EPO increases and induces an increase in erythrocyte and hemoglobin concentration. These changes increase blood's capacity for oxygen delivery to the working muscles (Cheung, 2009; Gore, Clark, & Saunders, 2007; McArdle et al., 2009; Wilber, 2004). In the first 3 hours after being exposed to high altitude, the blood’s EPO concentration starts to increase and maintains the increase for two or three days (Kenney et al., 2011) and returns to the baseline levels after 3 weeks (Hoffman, 2002).

Moreover, there are hypoxia-induced physiological changes in the skeletal muscle like increment of skeletal muscle capillarity which improves the extracting oxygen from the blood in exercising muscles. Also, concentrations of myoglobin, mitochondrial oxidative enzyme activity and the number of mitochondria increase as a result of altitude training. Thus, aerobic energy production improves (Fox et al., 1988; Vargas Pinilla, 2014; Wilber, 2004).

On the other hand, acute altitude exposure increases the blood lactate concentration during submaximal and maximal exercise but with altitude acclimatization it decreases. This physiological response is regarded as lactate paradox (McArdle et al., 2009; Wilber, 2004).

One of the potential mechanisms for altitude-induced performance improvement is the ability of skeletal muscle to buffer H+ which has importance for acid-base and pH regulations (Gore et al., 2007; Vargas Pinilla, 2014) and also for compensation for the decreased buffer capacity of blood based on the hyperventilation due to the decreased PO_2 (Vargas Pinilla, 2014). The enhancement of the skeletal muscle buffering capacity for the H^+ concentration is a non-hematologic muscle adaptation (Cheung, 2009; Gore et al., 2007; Wilber, 2004). Buffering capacity development retards muscle fatigue and may provide advantages for aerobic and anaerobic performance (Wilber, 2004).

In brief, immediate responses to altitude exposure include hyperventilation and increase in blood flow during rest and submaximal exercise, and also increase in submaximal exercise heart rate and in submaximal cardiac output and unchanged stroke volume. Long-term adjustments contain regulation of acid-base balance, increase in hemoglobin concentration, hematocrit, the total number of red blood cells and also increase in capillarization of skeletal muscle, mitochondrial density, aerobic enzymes in the muscle (McArdle et al., 2009).

2.1.2. Exercise at Altitude

At altitude, atmospheric pressure, PO_2 and air density decrease. Because of that O_2, CO_2 and N_2 percentages at altitude are the same as at sea level, any difference occurred in the partial pressure of these gases is owing to the atmospheric or barometric pressure changes. The decrease in the PO_2 at altitude directly affects the saturation of hemoglobin and oxygen transport (Powers & Howley, 1996). Therefore, altitude training is applied in order to improve performance by the athletes especially from endurance-based sports (Álvarez-Herms, Julià-Sánchez, Hamlin, et al., 2015; Wilber, 2004).

Altitude impairs the endurance events, however, especially moderate altitude, does not weaken the anaerobic activities like 100 m to 400 m sprints, and can even improve them. The reason is that most of the energy is supplied by the adenosine triphosphate (ATP), phosphocreatine, and glycolytic systems rather than the oxygen transport system and aerobic metabolism during these activities (Kenney et al., 2011) and acute hypoxia has no effect on anaerobic alactic or lactic energy production (Wolski, McKenzie, & Wenger, 1996).

In terms of acute effect, long term performances (> 2 min) depends on the oxygen delivery and are affected by decreased PO_2 (McArdle et al., 2009; Powers & Howley, 1996). Exposure to altitude up to 4300m decreases the maximal O_2 consumption by 2% to 29%. Because of the VO_2max and SO_2 reductions, aerobic performance decreases at altitude (Wilber, 2004).

On the other hand, short-term (≤ 2 min) anaerobic performances are not affected by the low PO_2 due to the fact that performance is not limited by the O_2 transport to the muscle (Fox et al., 1988; McArdle et al., 2009; Powers & Howley, 1996). On the contrary, high-altitude provides advantages for the activities based on anaerobic metabolism such as 100m sprint and high jump with decreasing the effect of gravity (Günay, Tamer, & Cicioğlu, 2010). For the anaerobic performance, peak and average power are not negatively affected by altitude in untrained persons, but in elite athletes altitude may damage the power with relatively high workloads (Wilber, 2004).

2.1.3. Sea Level Anaerobic Performance

There have been fewer studies conducted on anaerobic performance to investigate the effects of altitude training, compared to those applied on aerobic performance (Friedmann, Frese, Menold, & Bärtsch, 2007; Wilber, 2004). Aerobic metabolism makes less contribution to total energy production in anaerobic events (≤ 60 sec). Therefore, the increase in RBC mass and hemoglobin at altitude may not have a significant effect on sea level anaerobic performance. Nevertheless, H^+ buffering capacity enhancement may have additive effect on anaerobic performance because of the fact that increased blood lactate levels and H concentrations lead to skeletal muscle fatigue due to the impairment of actin-myosin cross-bridge cycling, reduction in sensivity of troponin for calcium and inhibition of phosphofructokinase enzyme and thus reduction in anaerobic energy production by glycolysis (Wilber, 2004).

2.1.4. Live Low-Train High

There are current altitude training models consisting of Live High-Train High (LHTH), Live High-Train Low (LHTL) and Live Low-Train High (LLTH) (McLean et al., 2014; Wilber, 2004).

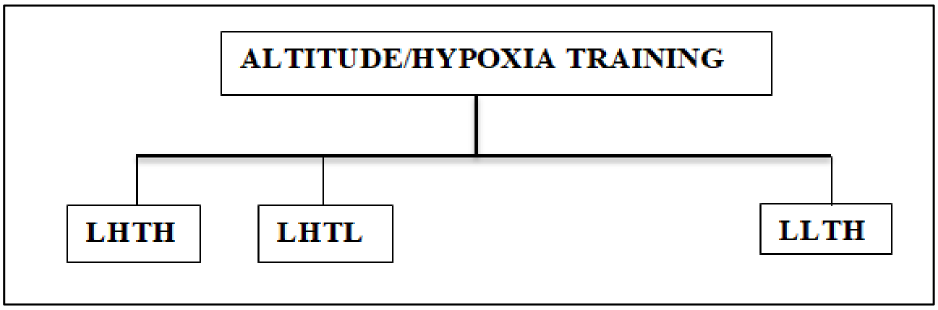


Figure 2.1 Contemporary Altitude Training Models (Wilber, 2011)

In LHTH and LHTL methods, the dose of hypoxia requires partially prolonged exposure (at least 2 weeks / more than 12 hours per day) (McLean et al., 2014). Conversely, short term activities (<1min), which do not base on the oxidative metabolism, appears to provide benefits immediately when applied under altitudes conditions (Feriche et al., 2017). Therefore, Live Low-Train High (LLTH) model has gained importance (Brocherie et al., 2017; McLean et al., 2014).

In this technique, athletes live under normoxic conditions but do their training under hypoxic conditions. Therefore, LLTH does not generate a sufficient stimulus to elicit the hematological changes related to LHTH and LHTL models (McLean et al., 2014).

The effectiveness of LLTH is controversial. There are studies stating that LLTH improves sea-level endurance performance and muscle performance, but also the studies reporting no benefits compared to the normoxia training are available (Lecoultre et al., 2009). In other respects, the LLTH seems to have potential to provide training adaptations based on the anaerobic metabolism and may produce contribution to short-term high-intensity maximal intermittent exercises (Álvarez-Herms et al., 2014; McLean et al., 2014).

In the literature, especially four types of LLTH with using systemic hypoxia are stated including continuous training in hypoxia (CHT), interval hypoxic training (IHT), repeated sprint training in hypoxia (RSH) and resistance training in hypoxia (RTH) (Girard et al., 2017; McLean et al., 2014). There is, in fact, an extra method mentioned under the title of LLTH named as intermittent hypoxic exposure (IHE). However there is no training during exposure sessions in this method and it was reported that IHE induces neither continuous physiological adaptations nor improved exercise performance when applied alone (Girard et al., 2017; McLean et al., 2014).

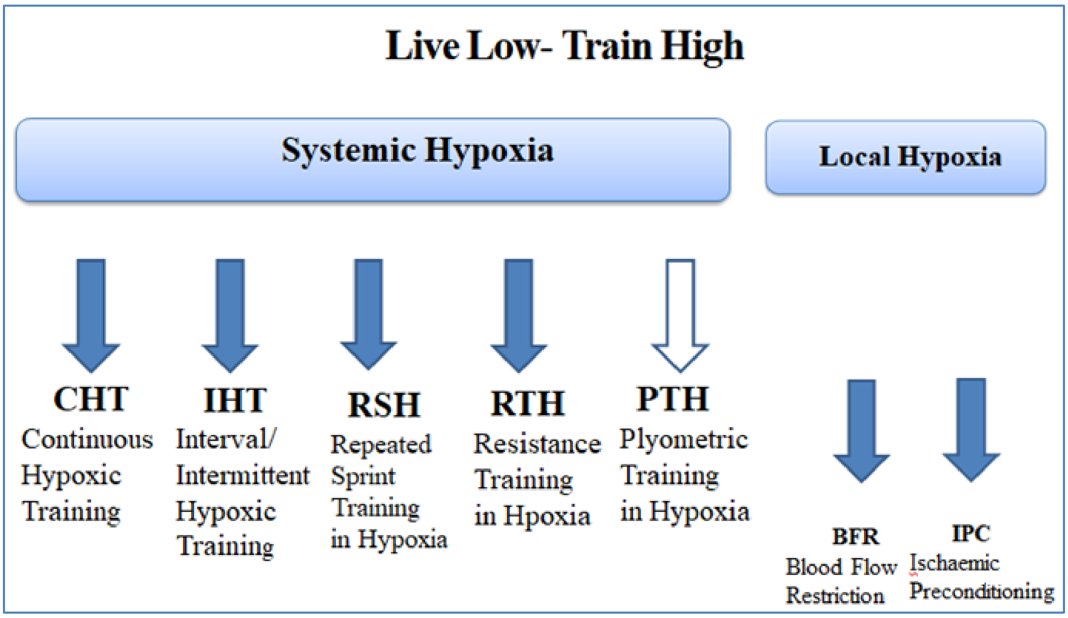


Figure 2.2 Live Low Train High Training Methods

2.1.4.1. Systemic Hypoxia

2.1.4.1.1. Continuous Hypoxic Training

It is suggested that low-intensity exercise in hypoxia exceeding 30 minutes should be stated under the title of CHT different from IHT (Millet, Faiss, Brocherie, & Girard, 2013). The use of endurance training with normobaric hypoxia seems promising. Hypoxia may produce additive effects on responses to endurance training despite reduced exercise intensity compared to the exercise in normoxia, due to the synergistic effect of hypoxia and exercise on muscular and systemic metabolism (Haufe, Wiesner, Engeli, Luft, & Jordan, 2008). However, there are also CHT studies in which hypoxia does not provide an extra benefit (Debevec et al., 2010; Ventura et al., 2003). The absence of improvement in aerobic-based performance may be owing to the decrease in cardiovascular function associated with lessened absolute exercise intensity in hypoxia (McLean et al., 2014). Because LLTH applications are more adaptive to the mechanisms related to the anaerobic capacity, the intensity of training in CHT may be insufficient to provide greater adaptation and performance improvement than matched one in normoxia (McLean et al., 2014).

2.1.4.1.2. Intermittent/Interval Hypoxic Training

It is thought that aerobic and anaerobic interval training would supply additional performance improvements when combined with the stress of hypoxia in comparison to the identical training in normoxia. However, detailed analyses revealed that IHT provides inadequate benefits for the developments of sea level performance compared to the equalized one in normoxia (Faiss, Girard, & Millet, 2013). Whereas most of the well-controlled researches presented no extra benefit of the hypoxic stimulus, the limited number of studies recommends some criterions in order to gain greater improvements from IHT, such as high-intensity intervals, anaerobic rather than aerobic performance to be measured and suitable training intensity and volume in normoxia to be matched with IHT (McLean et al., 2014).

2.1.4.1.3. Repeated Sprint Training in Hypoxia

Repeated sprint training in hypoxia is a training method consisting of the repetitions of short all-out sprints applied in hypoxia with incomplete recoveries (Brocherie et al., 2017; Girard et al., 2017). When performed in hypoxia, the physiological stress of training increases and makes the training more dependent on anaerobic pathways and the contribution of anaerobic metabolism becomes greater for the total energy production (Scott, Goods, & Slattery, 2016). RSH improves sprint speed or decreases the sprint time extension more than RSN (Girard et al., 2017). Also, it provides greater gains in repeated sprint ability compared to RSN (Brocherie et al., 2017). This can be due to the improved blood perfusion in RSH (Girard et al., 2017). The reason is that phosphocreatine breakdown and inorganic phosphate (Pi) accumulation in muscle are very high during the repeated sprints and this metabolite accumulation may impair the force production especially in fast-twitch fibers, and in this case, when the blood flow increases, removal of metabolites increases and the fatigue can be delayed during the repeated sprint ability test (Brocherie et al., 2017). The other reason for improved exercise performance following RSH is the increased fast twitch fiber recruitment (Brocherie et al., 2017; Faiss, Girard, Millet, 2013; Girard et al., 2017; Scott et al., 2016). Another one is specific molecular adaptations resulting from the oxygen-sensing pathway such as capillary-to-fiber ratio, oxidative enzyme activity and myoglobin content which are not observed or appear in a lesser degree in normoxia (Brocherie et al., 2017; Faiss, Girard, Millet, 2013). Also it has been stated that RSH leads to improvements in buffer capacity, glycolytic enzyme activity, lactate exchange and removal, and pH regulation (Gatterer et al., 2014).

2.1.4.1.4. Resistance Training in Hypoxia

Training in hypoxic conditions is also recommended in order to improve some adaptations related to resistance training. It is known that resistance training enhances maximal strength, power production and reduce fatigability by several adaptations like hypertrophy and modified motor recruitment patterns (McLean et al., 2014). In regard to the resistance training, the possibility of greater strength and hypertrophy gains following resistance training in hypoxia than identical training in normoxia is reported in the literature (Chycki et al., 2016; Girard et al., 2017; McLean et al., 2014). For instance, Kon et al., (2014) found improvements in muscle size and strength in consequence of HRT and also significantly greater muscular endurance compared to the normoxia group.

Adaptations to RTH are more related to muscle strength and hypertrophy. A number of possible mechanisms are available in previous studies. One possible reason is the increment of motor unit recruitment (Inness et al., 2016; Scott et al., 2016; Scott, Slattery, Sculley, & Dascombe, 2014). Premature fatigue occurs in the fibers initially recruited due to the metabolic acidosis and extra motor units are activated in order to continue the same level of force production. The more motor units are recruited, the larger part of the muscle is stimulated for adaptation (Scott et al., 2016). The other one is cell swelling based on metabolite accumulation in the cells. Also, cellular swelling may induce increment in protein synthesis and decrement in protein degradation in a series of cell types, even in muscle cells (Scott et al., 2016). Moreover, increase of growth hormone concentrations is the other possible reason for hypertrophy in consequence of RTH (Inness et al., 2016; Kurobe et al., 2015; Scott et al., 2016). Kurobe et al 2015, found resistance training produced greater muscle hypertrophy under hypoxic condition than that under normoxic condition. Also, serum growth hormone concentrations after hypoxia exercise were found significantly higher than those after the normoxia exercise.

One of the mechanisms underlying the increases in muscle strength following RTH is neural factors (Kurobe et al., 2015). RTH enhances muscle fiber firing rate (Inness et al., 2016). In the RTH it is known that adding the physiological stress of hypoxia makes the training more dependent on anaerobic metabolism (Scott et al., 2016). It is reported that neural adaptations following strength training are related to anaerobic performance improvement. The mechanisms supplying peak anaerobic power enhancement after strength training can be related to the increased force production and neural adaptation like increased motor neuron firing rate and muscular coordination (Buranarugsa, Oliveira, & Maia, 2012).

2.1.4.1.5. High Intensity/Explosive Exercise In Hypoxia

Short-term activities based on non-oxidative metabolism appear to provide immediate benefits when applied under hypoxia conditions compared to the activities based on aerobic metabolism. The hypoxic environment produces potential advantageous for the advancement of muscle performance with improvement of hypertrophy and increments in strength and speed of explosive movements (Feriche et al., 2017). As mentioned before, resistance and repeated sprint exercises are described as multiple, maximal or submaximal efforts divided by incomplete recoveries (Scott et al., 2016). And high intensity trainings in hypoxia lead to improvements of buffer capacity, lactate exchange and removal, tissue O_2 extraction, glycolytic enzyme activity; especially enhanced muscular perfusion, pH regulation in RSH (Gatterer et al., 2014) and increment of motor unit recruitment and growth hormone in RTH (Inness et al., 2016).

On the other hand, terrestrial altitude seems more advantageous to improve explosive speed probably due to increased anaerobic metabolism and reduced air density compared to the simulated hypoxia (Feriche et al., 2017; Powers & Howley, 1996; Wilber, 2004). It provides velocity and power developments, but this kind of improvements for normobaric hypoxia still need clarification (Feriche et al., 2017).

However, it is reported that moderate exposure to real (terrestrial altitude) or simulated (normobaric) hypoxic conditions do not damage the ability to execute force rapidly (Feriche et al., 2017). For instance, García-Ramos et al (2016) found that a simultaneous strength and endurance training programs with LHTH method (2320 m) did not negatively affect swimming start time and loaded squat jump performance. In another study, Garcia-Ramos et al (2014) detected an improvement in vertical jump performance after a 2-week training camp including pool and dry land training at (2320 m) altitude. Also, Álvarez-Herms et al (2014) studied a 4-week strength training in the hypoxic environment (simulated altitude of 2500m), and found non-significant increases in SJ and CMJ. In different research investigating the effects of 5-week repeated sprint training, which also includes plyometric exercises, in normobaric hypoxia (2900m), Brocherie et al., (2015) found greater improvements in explosive strength and sprint performances after RSH than those in RSN.

There is no solely explosive exercise training in the literature to the best of our knowledge. Nevertheless, according to Feriche et al., (2017), hypoxia-induced physiological mechanisms in respect to explosive exercise performance are under 3 main headings. One of them is related to anaerobic metabolism (Feriche et al., 2017). Stimulation of anaerobic metabolism following maximal exercise in hypoxia especially strength training provides a number of potential benefits. Due to the reduced energy from aerobic pathways, a compensatory mechanism is developed by increasing the energy production from anaerobic pathways. During the recovery phase after exercise the contribution of anaerobic pathways increases. The ability to tolerate waste product accumulation from anaerobic systems enhances. Muscular buffer capacity improves (Álvarez-Herms et al., 2014). Also, the other mechanism is related to the neural adaptation. It is stated that the improvement in speed movements can be due to the improvement of the firing frequency of motoneurons and spinal reflexes (Feriche et al., 2017). Moreover, it was previously stated that one of the underlying mechanism for muscle strength development following RTH is neural factors (Kurobe et al., 2015) and RTH enhances muscle fiber firing rate (Inness et al., 2016). The last adaptation is about metabolic stress (Feriche et al., 2017). As mentioned previously, increased metabolic stress leads to various physiological processes related to muscle hypertrophy such as improved fast twitch fiber recruitment and increased growth hormone concentrations (Scott et al., 2016).

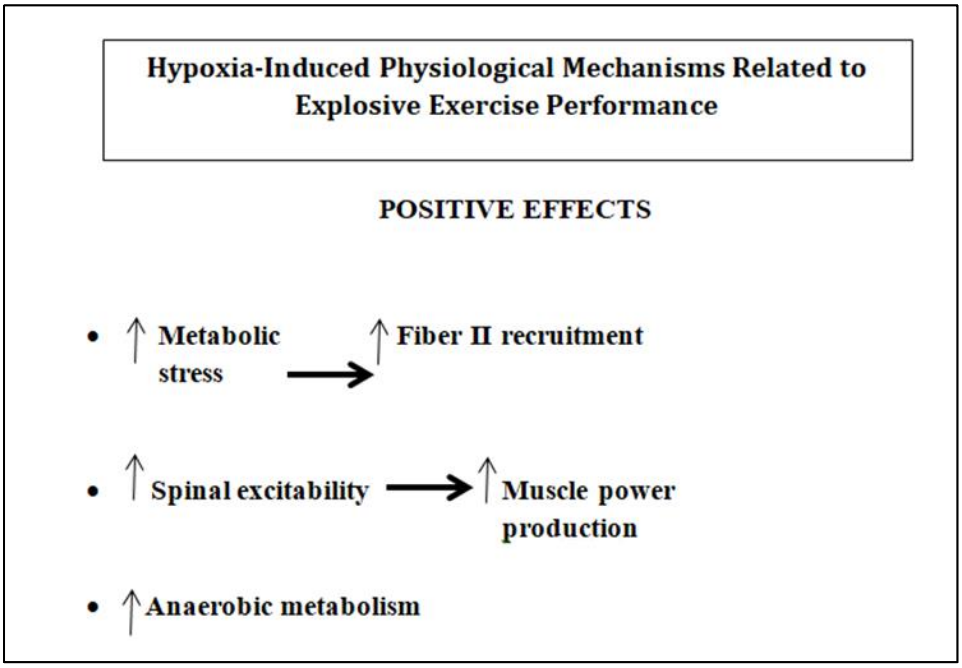


Figure 2.3 Hypoxia-Induced Physiological Mechanisms for Explosive Performance (Feriche et al., 2017)

2.1.4.2. Local Hypoxia

2.1.4.2.1. Blood Flow Restriction

The BFR technique is an application of creating a local hypoxic environment in exercise with using a tourniquet, inflatable cuff or elastic bandage all over the proximal edge of the limb in order to block the distal blood flow (Scott et al., 2014).

In the field of sport, the effects of BFR have been investigated mostly on hypertrophy and strength gains and therefore BFR has been used with resistance exercises (Abe et al., 2010; Fahs, Loenneke, Rossow, Tiebaud, & Bemben, 2012). Resistance exercises used with BFR provide muscle hypertrophy at a similar level to the traditional high-intensity resistance exercises, with much lower exercise intensity (Abe et al., 2010; Ozaki et al., 2011; Yokokawa, Hongo, Urayama, Nishimura, & Kai, 2008). BFR training can lead to significant muscle hypertrophy even at a low intensity such as 20% of 1RM. The training intensity of 20% of 1RM is considered as equivalent to the intensity of daily life physical activity when evaluated by electromyography and metabolic measurements (Abe, Kearns, & Sato, 2006; Loenneke, Wilson, & Wilson, 2010; Yokokawa, Hongo, Urayama, Nishimura, & Kai, 2008). Therefore, low-intensity (20-50% of 1RM) resistance training with BFR is recommended as an alternative to traditional high-intensity resistance training programs (Fahs et al., 2012; Manimmanakorn, Hamlin, Ross, Taylor, & Manimmanakorn, 2013; Park et al., 2010; Patterson & Ferguson, 2010; Yasuda, Loenneke, Ogasawara, & Abe, 2015).

2.1.4.2.2. Ischaemic Preconditioning

The implementation of repeated sessions of ischemia that continue with reperfusion is named as ischemic preconditioning (IPC) (Bailey et al., 2012). Indeed, IPC was improved in order to provide local or systemic protection for organs against following bouts of ischemia, but has also been recommended as an ergogenic aid for performance improvement (Girard et al., 2017; Incognito, Burr, & Millar, 2016).

Even though indications for the advantageous effects of IPC on training performance are available, a clear conclusion about the effects has not yet been reached (Salvador et al., 2016). The most consistent results are related to the developments of time-trial performance (Incognito et al., 2016).

2.2. Plyometric Exercise

2.2.1. Basics of Plyometrics

While muscular strength is described as the force or tension that a muscle or muscle group can reveal against a resistance in one maximal effort (Fox et al., 1988), power is the ability to generate the greatest potential force in the shortest amount of time (Bompa, 1999). Strength acquisition can be converted into power just by using specific types of power training. Plyometric training is one of the most successful training methods to improve power, and also known as stretch-shortening cycle (SSC) (Bompa, 1999).

SSC refers to the process of muscle lengthening (in an eccentric contraction) followed by a rapid shortening (concentric contraction) (Bompa, 1999; Chu & Myer, 2013). A stretched muscle ahead of a contraction makes more powerful and more rapid contraction (Bompa, 1999). Therefore, the ability of the muscle-tendon unit to generate maximal force within the shortest time is improved via SSC (Chu & Myer, 2013; Markovic & Mikulic, 2010). This combination of speed and strength ability is named as power (Chu & Myer, 2013; Sandler, 2005).

Plyometrics compose of the activities of skipping, hopping, jumping and throwing (Shah, 2012). While standing jumps, bounds, multiple hops and jumps, box drills and depth jumps are known as plyometric drills for the lower body; catches, medicine ball throws and different types of push-ups are used for the upper body (Haff & Triplett, 2015). Lower body exercises are based on rapid foot movements and required to leave the ground quickly (Shah, 2012). When jumping, a large amount of force is needed in order to impel the body upward. The limbs of the body must be able to exhibit very quick flexion and extension to leave the ground (Bompa, 1999). As for the upper body exercises, plyometrics relies on the training of the muscle to react more quickly to the external forces by using the medicine balls (Shah, 2012). Plyometric exercises depend on rapid action to reach the required power (Bompa, 1999).

In terms of SSC, movements are categorized as either fast, which has contact time lower than 250 ms, or slow of which contact time exceeds 250 ms (Markovic & Mikulic, 2010; Reilly, Cabri, & Araújo, 2005). While the effectiveness of the fast SSC, which is accepted as reactive strength, is tested by DJ, the effectiveness of the slow SSC is tested by pre-stretch increment in the vertical jump (during Countermovement jump and squat jump) in lower extremities (Markovic & Mikulic, 2010). Reactive strength is referred to as the ability for transition quickly from an eccentric to a concentric contraction (Reilly et al., 2005).

The complete sequence of eccentric, isometric and concentric actions is named as the stretch-shortening cycle (Fleck & Kraemer, 1997). The definitions of these three main types of muscular contractions are as follows.

Eccentric contraction briefly means the lengthening of a muscle during contraction (Fox et al., 1988). It is a dynamic contraction type, which muscles generate force while lengthening. The thin filaments are moved away from the sarcomere center (Kenney et al., 2011).

There is tension development but the length of the muscle does not change during **isometric contraction** (Fox et al., 1988). Muscle produces force with unchanged muscle length and also with unchanged joint angle, this is because, it is also named as static contraction (Kenney et al., 2011). During this contraction because of that the external force is much greater than the internal force, which can be generated by the muscle, the normal position of thin filaments does not change and the muscle does not shorten (Fox et al., 1988; Kenney et al., 2011).

Concentric contraction is simply described as shortening of a muscle during contraction (Fox et al., 1988). The thin filaments are moved towards the core of the sarcomere. These contractions are also named as dynamic contractions due to the joint movement (Kenney et al., 2011).

As mentioned above, the combination of speed and strength ability is named as power (Chu & Myer, 2013; Sandler, 2005). Three muscle characteristics directly affect speed and strength, and are developed by plyometric training. These are the muscle fiber type, muscle contraction speed, and neuromuscular firing speed and efficiency (Sandler, 2005).

2.2.1.1. Muscle Fiber Types

A single skeletal muscle includes fibers that have different shortening speeds and different characteristic for maximal force generation: type I (also named as slow or slow-twitch) fibers and type II (also known as fast or fast-twitch) fibers (Kenney et al., 2011). While there is one form of type I fiber, there are two major forms of type II fibers such as type IIa and type IIx in humans (Haff & Triplett, 2015; Kenney et al., 2011). Type IIx fiber in humans is nearly equal to the type IIb fiber in animals (Kenney et al., 2011).

Type I fibers are more efficient and have a high resistance to fatigue and a high capacity for aerobic energy supply (Haff & Triplett, 2015; Powers & Howley, 1996), but they have lower potential to develop rapid force (Haff & Triplett, 2015). Type I muscle fibers present a well aerobic endurance because of the high concentration of myoglobin, the large number of capillaries and high mitochondrial enzyme activities (McArdle, Katch, & Katch, 1991; Powers & Howley, 1996).

Type II fibers are inefficient and have a less resistance to fatigue, poor aerobic power (Haff & Triplett, 2015; Kenney et al., 2011; Powers & Howley, 1996), but they have higher potential to develop rapid force, high anaerobic power and myosin ATPase activity (Haff & Triplett, 2015; McArdle et al., 1991; Powers & Howley, 1996).

Type IIx fiber (fast-glycolytic fibers) is different from type IIa especially due to the capacity of aerobic-oxidative energy supply (Haff & Triplett, 2015). They show limited capacity for aerobic metabolism and less resistance to fatigue (Haff & Triplett, 2015; Powers & Howley, 1996), however, have a large anaerobic capacity due to the plenty of glycolytic enzymes (Powers & Howley, 1996). Type IIx fibers have the highest velocity of contraction owing to the myosin ATPase activity (Powers & Howley, 1996).

Type IIa fiber (fast-oxidative glycolytic fibers) can be regarded as a mixture of type I and type IIx fiber characteristics (Powers & Howley, 1996). Type IIa fibers possess a better capacity for aerobic metabolism and higher resistance to fatigue compared to type IIx (Haff & Triplett, 2015). However, when compared with type I fibers, type IIa produces more force, but also fatigue more easily (Kenney et al., 2011).

When stimulated, in order to arrive peak tension, approximately 110 ms is necessary for type I fibers, on the other side, nearly 50 ms is required for type II fibers. ATP is split more quickly in type II fibers compared to type I. Cross-bridge cycle is faster in type II fibers (Kenney et al., 2011).

While type I fibers are well suited for long and continuous aerobic exercises, type II fibers are suited for short-term, sprint activities besides other forceful muscular contractions which rely almost completely on anaerobic metabolism (Powers & Howley, 1996). As for the fast fiber subdivisions, type IIa fibers are the main fiber type for short, higher-intensity endurance events, such as the 400 m swim, whereas type IIx fibers are mostly used in highly explosive events like 50 m sprint swim or 100 m sprint (Kenney et al., 2011).

2.2.1.2. Muscle Contraction Speed

Maximal shortening velocity of individual fibers is measured to contrast the muscle fiber contraction speed. This highest speed, which a fiber can shorten, is indicated with Vmax. Because cross-bridge movement leads to shortening of muscle fibers, the rate of cross-bridge cycling designates the Vmax. The other determiner is the myosin ATPase activity (Powers & Howley, 1996), which is an enzyme splitting ATP in order to release energy for contraction (Kenney et al., 2011; McArdle et at., 1991). Muscle fibers that contain high myosin ATPase activities cause faster splitting of ATP and a fast release of energy needed for contraction and thus lead to a high speed of muscle shortening. Contrary to this, fibers containing low myosin ATPase activities present a low Vmax and shorten at slow speeds (Powers & Howley, 1996). The shortening speed is greater in fast fibers than slow types because they have more developed sarcoplasmic reticulum, therefore, they are more successful fibers to release calcium into the muscle cell (Kenney et al., 2011; McArdle et al., 1991; Powers & Howley, 1996), and contain a higher rate of ATPase activity (McArdle et al., 1991; Powers & Howley, 1996). Contraction speed is 5 to 6 times faster in type II fibers than type I (Kenney et al., 2011).

As for the movement velocity and muscular force relationship, there are two main points. Maximal force decreases when the velocity of movement increases, that is, the greatest force is generated at the slowest speeds of movement. This rule remains true for both slow- and fast fibers. The second point is that, at any absolute force executed by the muscle, the velocity of movement is greater in muscles that comprise a high percentage of fast fibers than those including mainly slow fibers (Fox et al., 1988; Powers & Howley, 1996).

On the other hand, according to the relationship between power and movement velocity, the peak power produced by a muscle increases as the velocities of movement increases up to a speed of 200-300 degrees/second. However, the power may even begin to decrease at very high movement speeds. Besides, at any movement speed, muscles consisting of a high percentage of fast fibers generate more power than those containing mainly slow fibers (Fox et al., 1988; Powers & Howley, 1996).

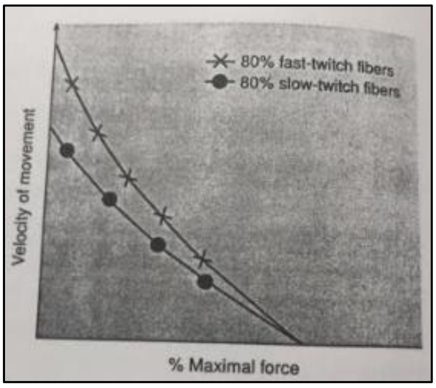


Figure 2.4 Muscle Force-Velocity Relationship

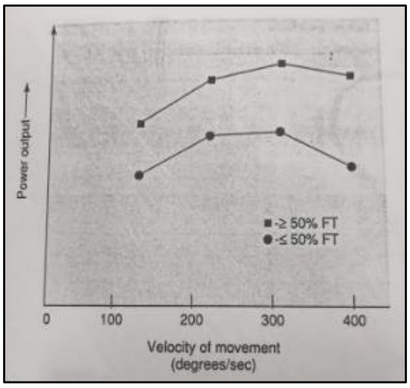


Figure 2.5 Muscle Power-Velocity Relationship

(Powers & Howley, 1996)

On the other hand, while maximal force is produced with slower contractions for concentric contractions, fast contractions reveal more force generation for the eccentric contractions (Kenney et al., 2011).

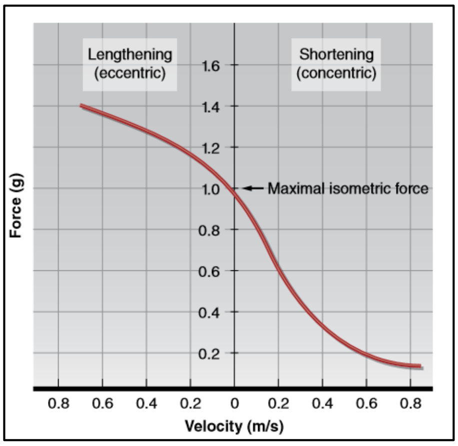


Figure 2.6 Relationship Between Muscle Lengthening and Shortening Velocity and Force Production (Kenney et al., 2011)

2.2.1.3. Neuromuscular Efficiency

Neuromuscular factors such as motor unit recruitment, firing frequency, synchronization and inter-muscular coordination influence the maximal muscular power (Cormie, McGuigan, & Newton, 2011).

From the viewpoint of motor unit recruitment, two main factors such as the number of motor units recruited and the number of muscle fibers in a motor unit influence the muscle force. The more fibers per motor unit produce a higher force. During a contraction, the number of motor units is determined by the load to which the muscle is exposed. ST fibers are recruited with moderate and low-intensity activity. When the load increases, more FT fibers are activated (Bompa, 1999). A motor unit is composed of the nerve fiber and the muscle it innervates (Hoffman, 2002). Type IIa and type IIx motor units possess more fibers than type I motor units (Kenney et al., 2011). The contraction strength in an entire muscle relies on the type and the number of muscle fibers recruited. When only a few motor units are recruited, the force generated is small (Powers & Howley, 1996).

Motor unit recruitment depends on the size of the neuron (Hoffman, 2002). An orderly recruitment of the motor units is named as size principle, which directly relies on the size of the motor neuron (Hoffman, 2002; Kenney et al., 2011). While FT motor unit has a larger nerve cell and innervates more than 300 fibers, the ST motor unit has a smaller nerve cell and connects less than 300 fibers (Kenney et al., 2011). Type I motor units are firstly recruited due to their smaller motor neurons. As a greater force for the muscle action is needed, type II motor units are recruited (Hoffman, 2002; Kenney et al., 2011). In conclusion, ST fibers are firstly recruited (Sandler, 2005), but, as long as the intensity increases, the number of fibers recruited also increases in type I, type IIa, type IIx, respectively (Kenney et al., 2011; Porcari, Bryant, & Comana, 2015). However, type II fiber can be firstly recruited during high-speed and powerful activities against the size principle, as an exception (Cormie et al., 2011; Haff & Whitley, 2001; Hoffman, 2002). This selective recruitment is important for force generation at very high speeds and may be an advantageous intrinsic neural mechanism supporting explosive exercise, and also can be improved by using specific training methods (Haff & Triplett, 2015).

On the other hand, as mentioned before, α-motor neuron and all muscle fibers it innervates constitute a single motor unit. Whereas each muscle fiber is innervated by just one α-motor neuron, each α-motor neuron innervates about a few thousand muscle fibers, based on the function of the muscle (Kenney et al., 2011). If a single stimulus is sent to the muscle, the muscle contracts to that electrical stimulus with a simple twitch (Powers & Howley, 1996), which is the smallest contractile answer of a muscle fiber or a motor unit (Kenney et al., 2011). When a motor unit is activated one time, the twitch does not generate a great amount of force. Yet, if the frequency of activation raises, the forces of the twitches start to overlap (Haff & Triplett, 2015). The muscle cannot have a chance to relax between stimuli when the frequency of stimulations increases and thereby there is an addition of twitches named as summation. If the frequency of stimuli maintains to increase further, a single sustained contraction occurs known as tetanus (Powers & Howley, 1996), which is the highest amount of force that the motor unit can produce (Haff & Triplett, 2015), and will last until the muscle tires or the stimuli are ended (Powers & Howley, 1996). The motor unit firing frequency implies the rate of neural impulses carried from α-motoneuron to the muscle fibers. Force generated during a contraction may be increased by 300–1500% with the increase of firing frequency of a motor unit, from minimum to maximum rate. It is stated that motor units start to firing at very high frequencies pursued by a fast decline throughout the ballistic contractions. Even when sustained for a short time, the high initial firing frequency leads to a rate of force development increase. Therefore, motor unit firing frequency is important for the improvement of maximal muscular power. It is reported that increases in motor unit firing frequency may support the force and power production particularly in the early phases of training, and can be prompted with the adaptations resulting from ballistic power training (Cormie et al., 2011). The increase in firing rate (vs. recruitment) also seems to be based on muscle size. While larger muscles rely more on motor unit recruitment for the force production enhancement, smaller muscles depend more on an augmented firing rate (Haff & Triplett, 2015).

As for the motor unit synchronization, it occurs when two or more motor units are activated simultaneously. It is stated as a nervous system adaptation, which helps the coactivation of many different muscles to improve the rate of force development. Indeed, synchronization is a kind of strategy for inter-muscular coordination. Inter-muscular coordination defines the proper activation, in terms of magnitude and timing, of agonist, antagonist and synergist muscles during an action. For an efficient movement, agonist activation requires to be supported by improved synergist activity and reduced contraction of antagonist muscles. Therefore, synchronization can affect force development during complex and multi-joint movements (Cormie et al., 2011). It is potentially more significant for the timing of force generation rather than the total force level improved (Haff & Triplett, 2015).

2.2.2. Physiology of Plyometric Exercise

During the plyometric exercise, the improvement of force production relies on mechanical and neurophysiological models (Haff & Triplett, 2015).

In terms of the mechanical approach, a quick stretch increases the elastic energy in the musculotendinous components and stores it. When this action is rapidly pursued by a concentric contraction, the release of the stored elastic energy increases the force generation (Haff & Triplett, 2015). In many mechanical elements, series elastic component (SEC) is main for plyometric exercise. The majority of the SEC composed of tendons, although it involves some muscular components. During eccentric muscle action, the SEC work as a spring and lengthens, and stored elastic energy. Immediately after, if there is a concentric contraction the stored energy is released (Haff & Triplett, 2015).

The neurophysiological models depend on the potentiation of concentric contraction by the way of stretch reflex (Haff & Triplett, 2015).

There are two kinds of muscle receptors that manage neural control and reflexes of skeletal muscle. One is muscle spindle and the other one is Golgi tendon organ (GTO) within the tendon of muscle (Sandler, 2005). Stimulating these receptors can facilitate, inhibit and modulate the agonist and antagonist muscles (Shah, 2012). The main function of the muscle spindle is to reveal stretch or myotatic reflex (Bağırgan, 2013).

2.2.2.1. Muscle Spindle

The muscle spindle is within the muscle belly (Bompa, 1999; Sandler, 2005), and sends information about the degree of muscle stretch to the spinal cord. When there is an excessive stretch, it sends signals to the spinal cord and a return message is given to the muscle to contract in order to prevent overstretching (Bompa, 1999; Sandler, 2005).

The main function of the muscle spindle is to reveal stretch or myotatic reflex (Bağırgan, 2013). One of the reasons for performance development provided by plyometric training is myotatic or stretch reflex (Thomas, 1988). It is one of the fastest reflexes in the human body due to the direct connection from muscle to the spinal cord (Chu & Myer, 2013) because of that the other reflexes must be delivered to the CNS (Central nervous system) (brain) before a reaction occurs (Chu & Myer, 2013).

The stretch reflex supplies an involuntary defense system to prevent sudden and powerful stretch (Thomas, 1988). When muscle spindle sends a signal to the muscle to contract, a reciprocal inhibition process occurs, in which information is given to the antagonistic muscle not to withstand the contraction process of agonist muscle (Sandler, 2005). Therefore, during plyometric exercises, the stretch reflex makes contribution to the development of muscular force production due to the combination of voluntary contraction and involuntary contraction based on the reflex (Thomas, 1988).

2.2.2.2. Golgi Tendon Organ

Golgi tendon organs (GTO) are located in the tendon and control the tension executed during contraction to prevent muscle from excessive force throughout the contractions (Powers & Howley, 1996).

Contrary to the muscle spindle, it exhibits an inhibitory effect (Shah, 2012). Muscle spindle activity is decreased during concentric contraction due to the shortening or starting to shorten of the muscle fibers. As for the eccentric contraction, myotatic reflex produces more tension in the extended muscle. When muscle tension reaches a high level, which can be harmful, the Golgi tendon organ fires in order to lower the excitation of muscle (Shah, 2012). While the muscle spindle signal instructs the same muscle to contract, GTO signal instructs the muscle to cease the contraction and to lead the antagonist muscle to contract (Sandler, 2005).

2.2.2.3. Elastic Energy

When a muscle is exposed to a prestretch, it starts to store up energy. If delivered rapidly, this energy contributes to muscle contraction. If the time when the muscle is kept stretched lasts too long, an explosive effect will not be generated (Sandler, 2005). On the contrary, when there is more rapid prestretch, the concentric contraction occurs more forceful (Bompa, 1999).

Through the eccentric contraction, the nervous system has the opportunity to send information to the brain about the amount of stretch, which is executed, and the amount of force required for the concentric contraction. In addition, GTO and muscle spindles find opportunity to work properly by means of the eccentric contraction. On the other side, when there is only concentric movement, there is no advantage of elastic energy nor a prestretch (Sandler, 2005).

Therefore, elastic energy storage and the stretch reflex activation of the muscle produce a combined effect in pre-stretching phase and thereby cause improvement in muscle performance (Fleck & Kraemer, 1997; Shah, 2012; Thomas, 1988). Plyometric exercise contributes to developments of muscular performance in several aspects. For instance, when the stretch reflex response speed is increased, performance may increase. The faster an eccentric contraction is executed, the greater the concentric force is generated (Shah, 2012).

On the other hand, GTO limits the force generated in the muscle in order to prevent muscle from excessive force. However, by applying proper training, the inhibitory effect of GTO may be decreased and it may be possible to increase the force production (Hoffman, 2002; Sandler, 2005; Shah, 2012).

Lastly, neuromuscular coordination may restrict the final speed of movement (Shah, 2012). Sophisticated coordination of agonist, antagonist and synergistic muscle groups is needed for the performance of SSC. During SSC executed rapidly, the agonist and synergistic muscle groups must be able to perform a large amount of force in a short time. When agonists and synergists are active, antagonist muscle groups should be relaxed in order to enhance this action. In addition, some training adaptations are necessary for a beginner to coordinate the stretch-shortening movements (Hoffman, 2002). Neuromuscular performance can be improved by enhancing neural efficiency with plyometric training. Activities of the muscle groups can be coordinated better by benefiting from the prestretch response. Greater force production can be achieved due to the neural adaptation regardless of morphologic change in the muscles (Shah, 2012).

2.2.3. Phases of Plyometric Exercises

There are three main phases of the plyometric exercise named as eccentric phase, the amortization phase and concentric phase (Sandler, 2005; Shah, 2012).

The eccentric phase starts when being prepared mentally for the movement and continues until the first stretch stimulus. Due to the pre-stretch the muscle spindle activity increases and this phase becomes advantageous (Shah, 2012). The increased force output related to the loading/eccentric phase depends on three mechanisms consisting of muscle potentiation, which relies on the alteration of muscle contractile properties and actin-myosin connection improvement, stretch reflex and the storage of elastic potential energy in the series elastic components. Series elastic components are actin-myosin filaments in the muscle and tendon, indeed, the tendon contributes further to the length alterations in muscle-tendon units (Chu & Myer, 2013).

The second phase is the amortization phase and defines as the amount of time between the eccentric contraction and the starting of the concentric force (Shah, 2012). Thereby it is described as the electromechanical delay or elapsed time between the eccentric and concentric contractions (Sandler, 2005; Shah, 2012). The decisive phase, which ultimately decides the synergistic gains from SSC, is the amortization phase (Chu & Myer, 2013). If the amortization phase lasts long, the elastic energy is misspent and released as heat with failing to activate the stretch reflex (Chu & Myer, 2013; Sandler, 2005; Shah, 2012). Therefore, a prolonged amortization phase leads to a loss of power (Bompa, 1999). Lastly, the unloading/concentric phase happens just after the amortization phase and contains shortening of the muscle-tendon unit (Chu & Myer, 2013).

The amortization phase is the most important one in plyometric exercise. However, the loading (eccentric) contraction time is also important for power improvement. If too much time is spent in order to absorb the impact because of the too great force or failing to balance, more time will be required to recover. Thereby, the amortization time will last longer and force output will decrease. For instance, jumping off a box, which is too high, takes more time to land or receiving a high-speed ball takes more time to provide control (Sandler, 2005). Plyometric activities require to stop one movement and exactly propel it back in the opposite direction (Sandler, 2005).

In brief, the eccentric phase is a process which stores the energy for the subsequent movement. Amortization phase is a time in which the energy is transformed into the kinetic energy or movement. The concentric movement is the last force generated to impel the body upward or forward (Sandler, 2005).

2.2.4. General Recommendations for Plyometric Training Prescription

The training time for a beginning program should carry on 20 to 30 minutes. An extra 10 to 15 minutes should be applied for warm-up and cool-down which includes stretching and low-intensity activities (Chu & Myer, 2013).

The number of training sessions more than 20 and the number of jump performances per training session more than 50 were recommended for the best results to get benefits from plyometric training (de Villarreal et al., 2009).

Normally plyometric exercises should be performed as explosively as possible at each repetition in order to improve power, but when learning a new exercise it can be performed at 70 to 80 percent until it is fully learned. For the first week participants execute the exercises at 70- to 80-percent, and then performed at 100-percent effort (Sandler, 2005).

The workload of training should be gradually increased with taking into consideration the physiological and psychological capabilities of each athlete, from beginner to peak efficiency level (Bağırgan, 2013).

The energy for plyometrics supplied from the anaerobic energy system and can last for 5 to 15 seconds of a strenuous effort. Therefore, sets for plyometric box training should not exceed six repetitions if the rest period is not long between the jumps. Over time, the number of repetitions can be increased because of that the phosphagen stores increase with training, but just one or two repetitions should be added, and maximal power on each repetition will probably become greater (Sandler, 2005).

If the exercise does not last very short, the rest intervals between sets should be at least two minutes. Some resources advise 30- to 60-second, but shorter intervals are not enough for the regeneration of the phosphagen stores and to remove the lactic acid (Sandler, 2005). Therefore, inadequate rest intervals reduce the effectiveness of the training (Chu & Myer, 2013; Sandler, 2005). 48 to 72 hours should be last between 2 sequential training. A work-to-rest ratio of 1:5 to 1:10 should be given for an appropriate performance (Chu & Myer, 2013; Shah, 2012).

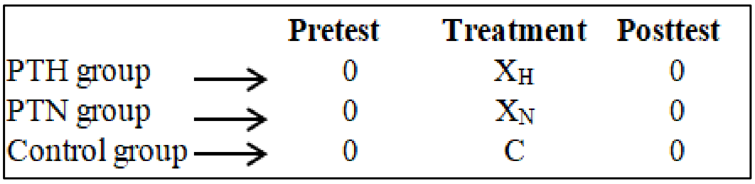
CHAPTER 3

METHOD

This chapter gives information about the research design, sampling and participants, experimental procedure, exercise protocol, data collection procedures, assessment devices and protocols, data analysis and limitations.

3.1. Research Design

This study was a Pretest-Posttest Control Group Design which was one of the experimental research designs.



		Pretest	**Treatment**	**Posttest**
PTH group	→	0	X_H	0
PTN group	→	0	X_N	0
Control group	→	0	C	0

Figure 3.1 The Diagram of the Design

In the experimental research, the researcher examines the effects of at least one independent variable on the dependent variable(s) (Fraenkel, Wallen, & Hyun, 2012). In this study, the independent variable was plyometric training in hypoxia and normoxia, and the dependent variables were the results obtained from body composition measurement, jump tests, sprint test, Wingate anaerobic power test and isokinetic strength test.

3.2. Sampling and Participants

The sample of the study consisted of 23 male volunteers from physical education students (Age = 20.39 ± 2.02; Height = 177±7.5) who did not regularly perform physical activity at least 3 days a week except for their college curriculum at Ankara University. They were randomly selected from ones who did not perform resistance and plyometric exercises in the last 6 months (Vissing et al., 2008).

Those who had undergone lower extremity surgery in the last 2 years or had an unhealed musculoskeletal disorder were excluded from the study (Chimera, Swanik, Swanik, & Straub, 2004; MacDonald, Lamont, & Garner, 2012). Participants, taking any kind of drugs in order to improve performance, anabolic steroid or growth hormone, were also excluded from the study (de Villarreal, González-Badillo, & Izquierdo, 2008; Ramírez-Campillo et al., 2014).

Participants were divided, according to their pretest performance results for controlling the subject characteristics threat to internal validity, into the groups of Plyometric Training in Hypoxia (PTH) (n = 8), Plyometric Training in Normoxia (PTN) (n = 7) and Control (n = 8). Because the researcher must determine which variables may create problems or bias and should try to minimize their effects (Fraenkel, Wallen, & Hyun, 2012), the sample assignment was made based on the pretest performance results of the subjects. The pretest performance values were ranked from highest to lowest and divided into three parts as low, medium and high points. The groups were formed by randomly assigning one person from these each three parts to the groups (hypoxia, normoxia and control), up to 10 subjects for each groups. 10 students were assigned to each group because the study actually started with 30 students. However, those who were repeatedly absent and have performed strength training with the current training simultaneously, despite our warning not to perform, were not included in the analyses. 2 students could not continue the current training because of their lower extremity injury occurred in their track and field lessons. Participants who could not attend the training for more than three times were excluded from the study. No significant difference was found in pre-test values between the three groups.

Written informed consent was obtained from all participants after giving information about the study design and the potential risks. Human research ethics committee of the Applied Ethics Research Center of Middle East Technical University approved the study.

The descriptive statistics of control and training groups are as follows. The mean and standard deviation of age and height were 20.63 ± 2.20 and 178.75 ± 6.32 for PTH group, respectively. The mean and standard deviation of age and height were 20.14±1.95 and 175.14±5.87 for PTN group, respectively. Lastly, the mean and standard deviation of age and height were 20.38±2.13 and 176.88±10.01 for Control group, respectively (Table 3.1).

Table 3.1
Descriptive Statistics of Control and Training Groups

	Groups	*n*	*M±SD*
Age	PTH	8	20.63±2.20
	PTN	7	20.14±1.95
	Control	8	20.38±2.13
Height	PTH	8	178.75±6.32
	PTN	7	175.14±5.87
	Control	8	176.88±10.01

3.3. Experimental Procedure

PTH group performed the plyometric training under normobaric hypoxic conditions at equal to 3.536 m with using a face mask attached to a portable hypoxic generator (Everest Summit II, Hypoxia, NY, ABD) for 3 days (Monday, Wednesday and Friday) per week during 8 weeks. PTN group performed the same training program in normoxic condition without a face mask. While mean oxygen saturation of PTH group varied between 82.8 and 84.7%, that of PTN group was between 95.3 and 96% during the exercises. Both groups were also instructed to continue their physical activities in their college curriculum. Also, an explanation was given for PTH group to prevent the placebo effect. It was said that the existence of any positive or negative effect of hypoxia on exercise is not yet known. As for the control group, they were asked to continue just their own physical activity in the curriculum without being exposed to any exercise protocol and to refrain from plyometric exercises. Pre-tests were conducted 2-3 days before the start of the training (Vissing et al., 2008) and post-tests were applied 5-6 days after the last training (Álvarez-Herms et al., 2014).

Figure 3.2 Hypoxico Summit II (Made in America) Portable Altitude Generator

Hypoxic conditions at normobaric environment were ensured with the Hypoxico Summit II (Made in America) exercise package. This device has the capacity of producing oxygen at the desired height till 6400 meters from the sea level and has a very sensitive low oxygen generator and very light air supported mask system. It also has height adjustment adaptor and automatic protocol practicing the skill and can adjust the level of oxygen at the required level between 9% (6400 meters height) and 21% (sea level). Oxygen level adjustments can be made with the buttons on the generator and can be followed on the screen (Karabiyik, 2017).

3.4. Exercise Protocol

10 minutes jogging and 5 minutes stretching were performed before starting the jump exercises. PTH group wear the face mask immediately after 10-min jogging. PTH group was exposed to hypoxia for 25- 35/40 minutes (from 1th to 8th week), including stretching, jumping exercises, and cooldown. Before starting the exercises and at the end of each exercise, oxygen saturation and heart rate were measured in order to check whether they were exposed to hypoxia. All subjects were asked to perform the exercises as explosively as possible. After plyometric

exercises, five minutes of cooldown exercises were performed and total training time lasted 35-50 min with the warm-up.

Jump exercises were composed of countermovement jump, squat jump, split squat jump and drop jump. **The countermovement jump** started with feet shoulder-width apart and continued with squatting, and immediately after, jumping straight up vertically as high as possible without waiting. **The squat jump** was applied after waiting a few seconds in a position at flexed knee at nearly 90°. **The split squat jump** started with bending the front leg 90° at the hip and 90° at the knee, and included switching the leg position at every turn; the front leg went to the back, the back leg comes through the front. **The drop jump** started with standing on a platform at a height of 40 cm and keeping the toes close to the front side of the platform. Then, it continued with a step and dropping from the platform then landing on both feet, and immediately after, jumping as high as possible. All jump exercises were applied hands-free.

Table 3.2
Training Program in the First Macrocycle

Weeks	**1.week**				**2.week**				**3.week**				**4.week**		
Sessions	**1**	**2**	**3**		**4**	**5**	**6**		**7**	**8**	**9**		**10**	**11**	**12**
Exercises	**a**				**b**				**c**				**a**		
Drop jump	3 x 5				3 x 7				3 x 9				3 x 5		
Split SJ	3 x 5				3 x 7				3 x 9				3 x 5		
CMJ	3 x 5				3 x 7				3 x 9				3 x 5		
Squat jump	3 x 5				3 x 7				3 x 9				3 x 5		
Per sessions	**60**				**84**				**108**				**60**		
Total	**180**				**252**				**324**				**180**		

Table 3.3
Training Program in the Second Macrocycle

Weeks	**5. week**			**6.week**			**7.week**			**8.week**		
Sessions	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Exercise	**d**			**e**			**f**			**d**		
DJ	4 x 9			4 x 11			4 x 13			4 x 9		
CMJ	4 x 9			4 x 11			4 x 13			4 x 9		
SJ	4 x 9			4 x 11			4 x 13			4 x 9		
Per sess.	**108**			**132**			**156**			**108**		
Total	**324**			**396**			**468**			**324**		

The workload of training was gradually increased (figure 3.2) and the exercise schedule was as follows (Table 3.2 and 3.3).

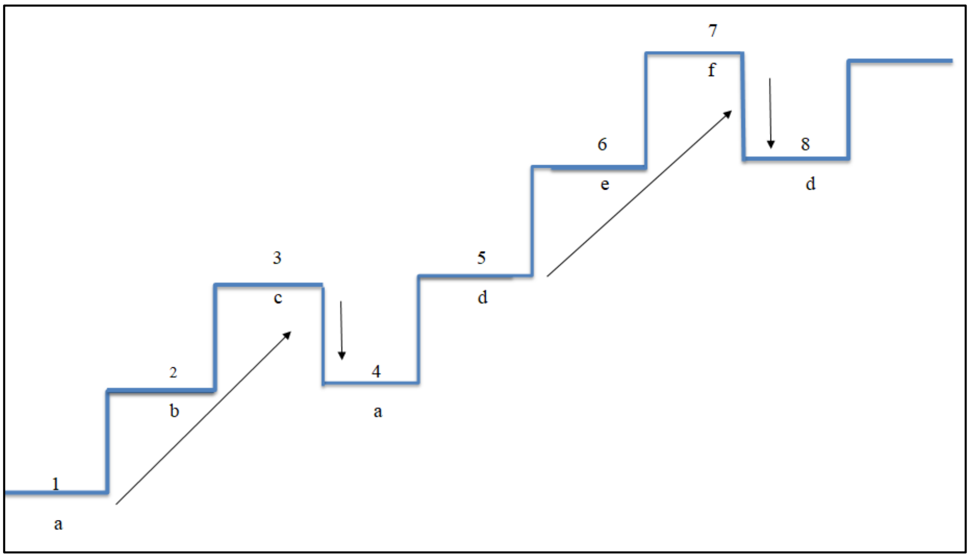


Figure 3.3 Progressively Increase of Training Load

For plyometric training, a work-to-rest ratio of 1:5 to 1:10 should be given for an appropriate performance (Chu & Myer, 2013). On the other hand, in hypoxia, work to rest ratios 1: 2 and 1: 3 are advised for IHRT while longer recovery (1: 5+) is generally used in repeated sprint ability tests. However, short incomplete recoveries are mostly recommended for performance improvement for both RTH and RSH (Scott et al., 2016) Therefore, in the current study, a rest ratio of 1: 5 for the sets lasting less than 15-20 seconds and 1:2 - 1: 3 was given for the sets exceeding 20 secs.

The training program was organized based on the program applied by Vissing et al. (2008), but some differences were adapted in order to enable performing plyometric exercises using a hypoxic generator. The important point of using this program is that the researchers tried to make their plyometric program comparable with conventional resistance training with regard to time and effort (Vissing et al., 2008).

One of the differences from the protocol used by Vissing et al. is exercise type. In that protocol, the hurdle jumps were used with CMJ and DJ, but in the current study SJ and Split SJ were used for the first 4 weeks, then split SJ was excluded and an extra set was added for the last 4 weeks. Furthermore, the literature supports to combine SJ, CMJ and DJ exercises to increase the training gains rather than performing of these exercises alone (de Villarreal et al., 2009).

Using extra weights with exercises does not significantly enhance the performance gains in plyometric training (de Villarreal et al., 2009). Therefore, extra weights were not required in this study, just hypoxia was preferred as an extra training stimulus.

The training protocol of this study was comprised of 24 training sessions and started with 60 jumps per session in the first week, as recommended (more than 20 sessions and more than 50 jumps per training sessions) in the literature (de Villarreal et al., 2009), and the number of sets and repetitions were progressively increased throughout the training period.

The energy for plyometrics supplied from the anaerobic energy system and can last for 5 to 15 seconds of a strenuous effort. Therefore, sets for plyometric box training should not exceed six repetitions if the rest period is not long between the jumps. However, over time, the number of repetitions can be increased because of that the phosphagen stores increase with training, but just one or two repetitions should be added, and maximal power on each repetition will probably become greater (Sandler, 2005). In this study, the number of repetitions was increased by 2 points for each week as recommended by Sandler (2005).

3.5. Data Collection Procedures

Before and after 8 weeks of training period, body height and weight measurements, bioelectrical impedance analysis, CMJ (countermovement jump) and SJ (squat jump) tests were performed. Anaerobic performance was measured via Wingate anaerobic power test. The composition of eccentric and concentric strength provides reactive strength. Lower limb reactive strength performance is frequently tested by using drop jump height (Gamble, 2009). Therefore, drop jump test was also applied pre- and post-training. Isokinetic leg strength tests were made as strength measurement. To evaluate the explosive strength gain in the horizontal plane 20 m sprint test was used.

While isokinetic strength tests, Wingate test and jump tests were performed on three different days, 20m sprint test and jump tests were performed on the same day.

The participants were instructed to avoid any strenuous training and to hold their daily habits such as diet, sleeping time, drinking water throughout the test period (Chen, Wang, Peng, Yu, & Wang, 2013).

3.6. Assessment Devices and Protocols

3.6.1. Body Height

Body height was measured while standing upright and barefoot. Participant kept his heels together and held his head straight. He took a deep breath and, when holding it and looking across, the highest point on the head was measured with a precision of 1mm (American College of Sports Medicine [ACSM], 2010). The measurement was taken with Harpenden stadiometer (Holtain, U. K.) in centimeters.

3.6.2. Body Weight and Bioelectrical Impedance Analysis

Body weight and body composition measurements were determined by the PlusAvis 333 analyzer (Jawon Medical, SOUTH KOREA). Participants were instructed to eat or drink at least 4 hours before the test and not to drink alcohol in the previous 48 hours, and also not to perform physical activity at least 12 hours prior to the measurement. They were asked to evacuate bladder 30 minutes before the test (ACSM, 2010).

All participants wore only shorts and a t-shirt, and were asked to remove the metallic materials during the bioelectrical impedance analysis. Participant stood barefoot on the device. Information such as age, gender, physical activity level was entered into the computer and was waited to be seen on the device screen. Then he held the grip electrodes of the device in both hands. Measurement was taken while waiting for approximately 10 seconds with straightened arms on both right and left sides.

Body weight (BW), body fat percentage (BFP), body fat mass (BFM), lean body mass (LBM), body mass index (BMI) variables were estimated by bioelectrical impedance analysis.

Figure 3.4 PlusAvis 333 Body Composition Analyser

3.6.3. Wingate Anaerobic Power Test

The test was carried out with a cycle ergometer named as Monark Peak Bike, Ergomedic 894 E model (Monark, Sweden) (Figure 3.4), and with a compatible computer and testing software.

The participants warmed up for 4 minutes at a speed of 60-80 rpm before the test. During the warm-up, the subjects were asked to perform 2 sprints (during the 1.30 and 2.30th minutes), each of which lasted 4 seconds. After the warm-up, 4 minutes of rest was given (Aras and Coskun, 2016).

For each participant, the seat distance, handlebar and seat height were adjusted. When adjusting the sitting height, one of the foot pedals were placed as parallel to the floor and the knee angle was 175° flexed, and the feet of the person were fixed to the pedal with the person. The test weight was selected 7.5% of the body weight for each subject. The test was started when the subject was ready. When the speed reached at 150 rpm, the weight pan dropped automatically. The subject was verbally encouraged through the 30-second test (Aras, 2014).

Figure 3.5 The Cycle Ergometer

3.6.4. Isokinetic Leg Strength Test

Isokinetic knee strength measurements were taken via the Isomed 2000 isokinetic dynamometer. The right and left leg quadriceps, hamstring and quadriceps/hamstring ratios of the participants were measured in 5 repeats at 60°/sec and 180°/sec angular speeds (Ölçücü, Erdil, Karahan, Cenikli, & Altınkök, 2011; Özkan, & Kin-İşler, 2010). It is thought that the first two to six contractions are generally suitable to assess the maximum torque and three to four repetitions are suggested by Perrin to achieve the maximum torque measurement (Perrin, 1993).

Before the isokinetic measurement, the participants ran for 5 minutes at 6 km speed in the treadmill for warming up and then practiced stretching exercises for 5 minutes. After this, the test was carried out in the sitting position in the isokinetic dynamometer, the participants were fixed to the seat from their abdominal region and middle of their femur with the help of a band and arms were folded across in order to prevent them from getting strength from their arms (Perrin, 1993; Wilkerson et al., 2004) and the dynamometer adjustments were made in accordance with the physical conditions of the subjects.

They exercised 2 maximal contractions following 3 submaximal contractions at each test velocity for warming up (Özkan, & Kin-İşler, 2010; Perrin, 1993). Following the warm-up exercises, 30 seconds of passive resting was given and the real measurements were made. The athletes conducted 5 maximal contractions for each level (60°/sec and 180°/sec). Testing practices started with the measurements at low velocities (Perrin, 1993).

As recommended by Perrin (1993) each test protocol started with a warm-up session consisting of both submaximal and maximal, and performed for each test velocity. Also, he recommends 30 seconds to 1 minute for recovery following four maximal repetitions and at least 1 minute or longer rest intervals were suggested for a 25-30 repetition endurance test (Perrin, 1993). 2 minutes of resting were given between the measurements of right and left leg. The athletes were verbally encouraged during the test.

Figure 3.6 Isokinetic System (Isomed 2000)

3.6.5. (20 m) Sprint Test

20 m sprint test was used as an indicator of explosive force-production capacity in the horizontal plane, which needs fast SSC exertion, in some studies (Ramírez-Campillo et al., 2014). Therefore, 20 m sprint test was performed before and after the training period, on a wooden running surface. To measure the sprint time, photoelectric cells (Newtest 100 (Finland)) were used with the infrared beams positioned at 20 m.

After a warm-up, participants executed 2 trials at half speed, and then three main trials were performed and the best one was used for the analysis. Three minutes rest intervals were allowed between the trials (de Villarreal et al., 2008; Ramírez-Campillo et al., 2014; Ramírez-Campillo, Andrade, & Izquierdo, 2013).

3.6.6. CMJ Test

CMJ and SJ were found the most reliable and valid field tests to evaluate the explosive power of the lower limbs by using a contact mat (Markovic, Dizdar, Jukic, & Cardinale, 2004).

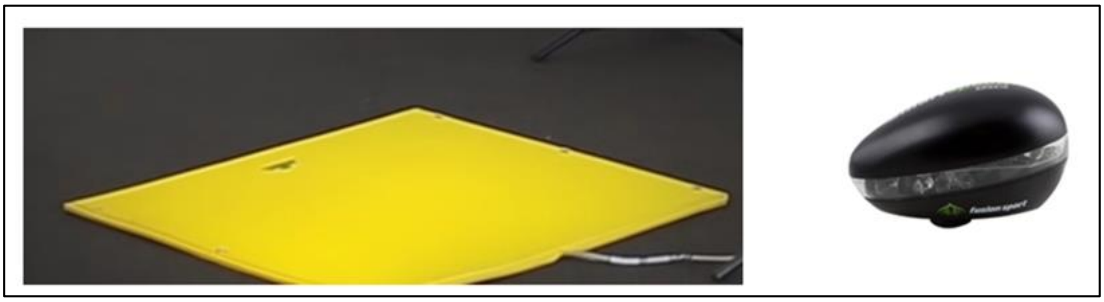


Figure 3.7 Smartspeed Lite Technology and Smart Jump Mat

Before starting jump tests, participants performed a standard warm-up consisting of 4-min jogging, 3-min stretching and several jumps (Young, Pryor, & Wilson, 1995).

In CMJ test, from a standing position, participants perform a fast downward movement and immediately vertically jump with a maximal effort, and then following the landing in an upright position they bend their knees. Participants were asked to perform the CMJ to execute maximal height on a jump mat (Smartspeed Lite system and Smartjumpmat).

They were instructed to keep their hands on hips during the jump to minimize the contribution of the arms (Ozbar, Ates, & Agopyan, 2014; Spurrs, Murphy, & Watsford, 2003). No restriction was imposed about the knee angle during the downward movement of the CMJ (Ramírez-Campillo et al., 2013; Spurrs et al., 2003). 3 trials were recorded, and the best one was used for the analysis (de Villarreal et al., 2008; Ozbar et al., 2014; Ramírez-Campillo et al., 2013) (Cherif et al., 2012; de Villarreal et al., 2008; Ozbar et al., 2014; Ramírez-Campillo et al., 2013). 15 seconds of rest was given between the trials (Ramírez-Campillo et al., 2013).

3.6.7. SJ Test

Another test to assess the explosive power of the lower limbs was the SJ as mentioned above. After waiting 3 seconds with a flexed knee at nearly 90° and with putting hands on hips, participants execute a vertical jump with a maximal effort, keeping the legs straight throughout, and then following the landing in an upright position they bend their knees (Chelly et al., 2010; Ramírez-Campillo et al., 2013).

3 trials were performed, and the best trial was used for the analysis. 15 seconds of rest was permitted between the trials (Ramírez-Campillo et al., 2013).

3.6.8. DJ Test

The test was performed on the jump mat (Smartspeed Lite system and Smartjumpmat) (Figure 3.7) and with keeping hands on hips to exclude the contribution of arm swing. Participant stood on a box at a height of 40 cm and then dropped to the force plate after he stepped off the box with holding the leading leg straight. And, the instruction was given for trying to jump as high as possible with the minimum contact time. He was also instructed to keep his knees and ankles fully extended when leaving the box and landing on the force plate. Each participant completed 3 trials. There were 15-second rest intervals between the trials (Chen et al., 2013; de Villarreal et al., 2008; Ramírez-Campillo et al., 2013). The best performance was evaluated for the statistical analysis (de Villarreal et al., 2008; Ramírez-Campillo et al., 2013).

Trials which contact times exceed 250 milliseconds were not included in the evaluations (Ramírez-Campillo et al., 2013). Drop jump height (cm), ground contact time (ms) and RSI (Reactive Strength Index) values were obtained and recorded in this test.

The Reactive Strength Index (RSI) is a component of the Strength Qualities Assessment Test (SQAT), which is used to distinguish the differences of strength qualities of sprinters and jumpers at the Australian Institute of Sport. It is calculated by dividing the jump height by the contact time during a drop jump. Reactive strength is referred to as the ability for transition quickly from an eccentric to a concentric contraction (Reilly et al., 2005).

RSI value was computed by using the following formula:

RSI = Jump height (meters) / Ground contact time (seconds) (Ball & Zanetti, 2012).

In this study a 40-cm box was used to test the DJ performances because of that it was mentioned as optimal drop height in some studies (Ball & Zanetti, 2012).

3.7. Data Analysis

Descriptive statistics were applied and reported as means and standard deviations for all variables. For the differences between the three groups, the Kruskal–Wallis H-test was performed. Then Mann–Whitney U-test was applied to determine which groups differ, and also Bonferroni correction was used not to inflate the Type I error rate, by dividing the critical value of .05 by the number of tests which were conducted (Field, 2009). The Wilcoxon signed-rank test was performed to compare the pre- and post-test results. Alpha value was accepted as 0.05. Statistical Package for Social Sciences version 22 was used for all analyses.

CHAPTER 4

RESULTS

In this chapter the results of the body composition analysis, jump and sprint test, Wingate anaerobic power test and isokinetic strength tests were given below.

4.1. Results of Body Composition

Intragroup mean, standard deviation and percentage changes of body composition variables of all groups were presented in Table 4.1. Body weight demonstrated 0.53% decrease in PTH group (*M* = 69.32, *SD* = 10.56 to *M* = 68.95, *SD* = 10.55), 0.15% increase in PTN group (*M* = 65.53, *SD* = 10.25 to *M* = 65.63, *SD* = 10.34) and 0.34% increase in Control group (*M* = 67.65, *SD* = 9.49 to *M* = 67.88, *SD* = 8.63). In body mass index (BMI), a 0.46% decrease in PTH group (*M* = 21.61, *SD* = 2.45 to *M* = 21.51, *SD* = 2.42), a 0.05% decrease in PTN group (*M* = 21.27, *SD* = 2.24 to *M* = 21.26, *SD* = 2.12) and a 0.28% increase in Control group (*M* = 21.59, *SD* = 2.20 to *M* = 21.65, *SD* = 1.94) were detected. As for the body fat percentage (BFP), a 8.17% decrease in PTH group (*M* = 14.68, *SD* = 3.80 to *M* = 13.48, *SD* = 2.86), a 9.43% rise in PTN group (*M* = 13.79, *SD* = 5.64 to *M* = 15.09, *SD* = 5.48) and a 4.13% increase in Control group (*M* = 13.81, *SD* = 4.83 to *M* = 14.38, *SD* = 3.63) were seen. Fat mass (FM) showed 10.14% reduction in PTH group (*M* = 10.36, *SD* = 3.58 to *M* = 9.31, *SD* = 2.37), 11.43% increment in PTN group (*M* = 9.27, *SD* = 4.45 to *M* = 10.33, *SD* = 4.88) and 4.41% increase in Control group (*M* = 9.30, *SD* = 3.53 to *M* = 9.71, *SD* = 2.74). In lean body mass (LBM), there was a 1.14% increase in PTH group (*M* = 58.97, *SD* = 8.20 to *M* = 59.64, *SD* = 9.30), a 1.71% decline in PTN group (*M* = 56.26, *SD* = 8.11 to *M* =

55.30, *SD* = 5.95) and 0.33% decrease in Control group (*M* = 58.35, *SD* = 9.54 to *M* = 58.16, *SD* = 8.19) (Table 4.1).

Table 4.1

Intragroup Mean, Standard Deviation and Percentage Changes of Body Composition Variables

Variable	**Group**	***n***	**Pre-test** ***M±SD***	**Post-test** ***M±SD***	**Change** ***(%)***
Body weight	PTH	8	69.32±10.56	68.95±10.55	0.53
	PTN	7	65.53±10.25	65.63±10.34	0.15
	Control	8	67.65±9.49	67.88±8.63	0.34
BMI (kg/m^2)	PTH	8	21.61±2.45	21.51±2.42	0.46
	PTN	7	21.27±2.24	21.26±2.12	0.05
	Control	8	21.59±2.20	21.65±1.94	0.28
BFP (%)	PTH	8	14.68±3.80	13.48±2.86	8.17
	PTN	7	13.79±5.64	15.09±5.48	9.43
	Control	8	13.81±4.83	14.38±3.63	4.13
FM (kg)	PTH	8	10.36±3.58	9.31±2.37	10.14
	PTN	7	9.27±4.45	10.33±4.88	11.43
	Control	8	9.30±3.53	9.71±2.74	4.41
LBM (kg)	PTH	8	58.97±8.20	59.64±9.30	1.14
	PTN	7	56.26±8.11	55.30±5.95	1.71
	Control	8	58.35±9.54	58.16±8.19	0.33

BMI: Body mass index, **BFP:** Body fat percentage, **FM:** Fat mass, **LBM:** lean body mass

Table 4.2

Kruskal Wallis Test Results for Intergroup Differences in Pre-test Values of Body Composition

Variable	***Group***	***n***	***Mean Rank***	***sd***	X^2	***p***
Body weight	PTH	8	12.69	2	.18	.92
	PTN	7	11.21			
	Control	8	12.00			
BMI (kg/m^2)	PTH	8	12.38	2	.08	.96
	PTN	7	11.43			
	Control	8	12.13			
BFP (%)	PTH	8	12.56	2	.10	.95
	PTN	7	11.93			
	Control	8	11.50			
FM (kg)	PTH	8	13.63	2	.71	.70
	PTN	7	11.07			
	Control	8	11.19			
LBM (kg)	PTH	8	12.94	2	.41	.81
	PTN	7	10.71			
	Control	8	12.19			

$p > .05$

According to pre-test results, there is no significant difference among three groups in body weight $H(2) = .18$, $p = .92$; BMI $H(2) = .08$, $p = .96$; BFP $H(2) = .10$, $p = .95$; FM $H(2) = .71$, $p = .70$; and LBM $H(2) = .41$, $p = .81$; $p > .05$ (Table 4.2).

According to post-test results, there is no significant difference among three groups in body weight $H(2) = .31$, $p = .86$; BMI $H(2) = .16$, $p = .92$; BFP $H(2) = .74$, $p = .69$; FM $H(2) = .68$, $p = .71$; and LBM $H(2) = .87$, $p = .65$; $p > .05$ (Table 4.3).

Plyometric training in hypoxia did not make a significant difference in body weight ($z = -1.12$, $p = .26$, $r = -.28$), BMI ($z = -.84$, $p = .40$, $r = -.21$), BFP ($z = -1.52$, $p = .13$, $r = -.38$), FM ($z = -1.47$, $p = .14$, $r = -.37$), LBM ($z = -1.12$, $p = .26$, $r = -.28$) between pre- and post-test results, $p > .05$ (Table 4.4).

Table 4.3

Kruskal Wallis Test Results for Intergroup Differences in Post-test Values of Body Composition

Variable	*Group*	*n*	*Mean Rank*	*sd*	X^2	*p*
Body weight	PTH	8	12.75	2	.31	.86
	PTN	7	10.86			
	Control	8	12.25			
BMI (kg/m^2)	PTH	8	12.31	2	.16	.92
	PTN	7	11.14			
	Control	8	12.44			
BFP (%)	PTH	8	10.88	2	.74	.69
	PTN	7	13.79			
	Control	8	11.56			
FM (kg)	PTH	8	11.56	2	.68	.71
	PTN	7	13.71			
	Control	8	10.94			
LBM (kg)	PTH	8	13.38	2	.87	.65
	PTN	7	10.14			
	Control	8	12.25			

$p > .05$

As for the normoxia group, there was no significant difference in body weight ($z = -.31$, $p = .75$, $r = -.08$), BMI ($z = -.14$, $p = .89$, $r = -.04$), BFP ($z = -.34$, $p = .74$, $r = -.09$), FM ($z = -.34$, $p = .74$, $r = -.09$), LBM ($z = -.17$, $p = .87$, $r = -.05$) between pre- and post-tests, $p > .05$ (Table 4.5).

Table 4.4

Intragroup Comparison of Body Composition Variables in PTH Group

Variable	*Post-pretest*	*n*	*Mean Rank*	*Sum of Ranks*	*z*	*p*	*r*
Body weight	Negative Ranks	6	4.33	26	-1.12	.26	-.28
	Positive Ranks	2	5	10			
	Ties	0	-	-			
BMI (kg/m^2)	Negative Ranks	4	3.63	14.50	-.84	.40	-.21
	Positive Ranks	2	3.25	6.50			
	Ties	2	-	-			
BFP (%)	Negative Ranks	5	4.60	23	-1.52	.13	-.38
	Positive Ranks	2	2.50	5			
	Ties	1	-	-			
FM (kg)	Negative Ranks	4	4.38	17.50	-1.47	.14	-.37
	Positive Ranks	2	1.75	3.50			
	Ties	2	-	-			
LBM (kg)	Negative Ranks	3	3.33	10	-1.12	.26	-.28
	Positive Ranks	5	5.20	26			
	Ties	0	-	-			

p >.05

Table 4.5

Intragroup Comparison of Body Composition Variables in PTN Group

Variable	*Post-pretest*	*n*	*Mean Rank*	*Sum of Ranks*	*z*	*p*	*r*
Body weight	Negative Ranks	2	4.50	9	-.31	.75	-.08
	Positive Ranks	4	3	12			
	Ties	1	-	-			
BMI (kg/m^2)	Negative Ranks	3	2.67	8	-.14	.89	-.04
	Positive Ranks	2	3.50	7			
	Ties	2	-	-			
BFP (%)	Negative Ranks	5	3.20	16	-.34	.74	-.09
	Positive Ranks	2	6	12			
	Ties	0	-	-			
FM (kg)	Negative Ranks	5	3.20	16	-.34	.74	-.09
	Positive Ranks	2	6	12			
	Ties	0	-	-			
LBM (kg)	Negative Ranks	2	6.50	13	-.17	.87	-.05
	Positive Ranks	5	3	15			
	Ties	0	-	-			

p >.05

No significant difference was found between pre- and post-test results in body weight (z = -.51, p = .61, r = -.13), BMI (z = -.28, p =.78, r = -.07), BFP (z = -1.05, p =.29, r = -.26), FM (z = -.98, p =.33, r = -.25), LBM (z = -.14, p = .89, r = -.04) in the control group p > .05 (Table 4.6).

Table 4.6
Intragroup Comparison of Body Composition Variables in Control Group

Variable	*Post-pretest*	*n*	*Mean Rank*	*Sum of Ranks*	*z*	*p*	*r*
Body weight	Negative Ranks	2	5.50	11	-.51	.61	-.13
	Positive Ranks	5	3.40	17			
	Ties	1	-	-			
BMI (kg/m^2)	Negative Ranks	4	4	16	-.28	.78	-.07
	Positive Ranks	4	5	20			
	Ties	0	-	-			
BFP (%)	Negative Ranks	2	5.25	10.50	-1.05	.29	-.26
	Positive Ranks	6	4.25	25.50			
	Ties	0	-	-			
FM (kg)	Negative Ranks	3	3.67	11	-.98	.33	-.25
	Positive Ranks	5	5	25			
	Ties	0	-	-			
LBM (kg)	Negative Ranks	4	4.75	19	-.14	.89	-.04
	Positive Ranks	4	4.25	17			
	Ties	0	-	-			

$p > .05$

4.2. Results of Sprint and Jump Parameters

Intragroup mean, standard deviation and percentage changes of sprint and jump parameters were represented in Table 4.7. 14.80%, 8.55%, 1.93% increase was seen in countermovement jump height (CMJ) in the groups of PTH (*M* = 37.77, *SD* = 6.67 to *M* = 43.36, *SD* = 5.03), PTN (*M* = 37.33, *SD* = 4.83 to *M* = 40.52, *SD* = 4.53) and Control (*M* = 37.87, *SD* = 5.57 to *M* = 38.60, *SD* = 6.40), respectively. A 16.06% increase in PTH group (*M* = 35.43, *SD* = 6.18 to *M* = 41.12, *SD* = 5.68), a 8.83% rise in PTN group (*M* = 35.91, *SD* = 6.42 to *M* = 39.08, *SD* = 5.55) and a 0.03% decrease in Control group (*M* = 35.98, *SD* = 5.67 to *M* = 35.97, *SD* = 5.22) were found in squat jump height (SJ). In drop jump height (DJ (cm)), while there was a 15.97% increase in PTH group (*M* = 32.81, *SD* = 5.95 to *M* = 38.05, *SD* = 5.55) and 7.89% increase in PTN group (*M* = 34.58, *SD* = 4.67 to *M* = 37.31, *SD* = 4.79), there was a 4. 34% decrease in Control group (*M* = 33.86, *SD* = 3.46 to *M* = 32.39, *SD* = 5.12). Drop jump ground contact time (DJ (ms)) demonstrated a 5.36% increase in PTH group (*M* = 221.38, *SD* = 17.46 to *M* = 233.25, *SD* = 18.67), a 1.76% decrease in PTN group (*M* = 219, *SD* = 26.48 to *M* = 215,14, *SD* = 21.87) and a 2.93% increase in Control group (*M* = 218, *SD* = 18.56 to *M* =

224.38, *SD* = 10.84). In reactive strength index (RSI), while 10% increment in PTH group (*M* = 1.50, *SD* = .35 to *M* = 1.65, *SD* = .31) and 9.38% increment in PTN group (*M* = 1.60, *SD* = .33 to *M* = 1.75, *SD* = .29) were found, 5.26% reduction was detected in Control group (*M* = 1.52, *SD* = .17 to *M* = 1.44, *SD* = .19). Sprint time showed a 3.42% decrease in PTH group (*M* = 3257.13, *SD* = 109.50 to *M* = 3145.75, *SD* = 83.62), 2.58% reduction in PTN group (*M* = 3209.29, *SD* = 76.11 to *M* = 3126.57, *SD* = 100.39) and 0.27% increase in Control group (*M* = 3192, *SD* = 138.94 to *M* = 3200.75, *SD* = 69.61) (Table 4.7).

Table 4.7
Intragroup Mean, Standard Deviation and Percentage Changes of Sprint and Jump Parameters

Variables	*Group*	*n*	*Pre-test M±SD*	*Post-test M±SD*	*Change (%)*
CMJ (cm)	PTH	8	37.77 ± 6.67	43.36±5.03	14.80
	PTN	7	37.33 ± 4.83	40.52±4.53	8.55
	Control	8	37.87 ± 5.57	38.60±6.40	1.93
SJ (cm)	PTH	8	35.43 ± 6.18	41.12±5.68	16.06
	PTN	7	35.91 ± 6.42	39.08±5.55	8.83
	Control	8	35.98 ± 5.67	35.97±5.22	0.03
DJ (cm)	PTH	8	32.81 ± 5.95	38.05±5.55	15.97
	PTN	7	34.58 ± 4.67	37.31±4.79	7.89
	Control	8	33.86 ± 3.46	32.39±5.12	4.34
DJ (ms)	PTH	8	221.38 ± 17.46	233.25±18.67	5.36
	PTN	7	219 ± 26.48	215,14±21.87	1.76
	Control	8	218 ± 18.56	224.38±10.84	2.93
RSI (m/sec)	PTH	8	1.50 ± .35	1.65±.31	10
	PTN	7	1.60 ± .33	1.75±.29	9.38
	Control	8	1.52 ± .17	1.44±.19	5.26
Sprint (ms)	PTH	8	3257.13 ± 109.50	3145.75±83.62	3.42
	PTN	7	3209.29 ± 76.11	3126.57±100.39	2.58
	Control	8	3192 ± 138.94	3200.75±69.61	0.27

CMJ: Countermovement jump, **SJ**: Squat jump, **DJ**: Drop jump, **RSI**: Reactive strength index

According to pre-test results of Kruskal Wallis Test, there is no significant difference among three groups in CMJ (countermovement jump height) *H*(2) =.06, *p* = .97; SJ (squat jump height) *H*(2) = .20, *p* = .91; DJ (drop jump height) *H*(2) = 1.09, *p* = .58; DJ (drop jump ground contact time) *H*(2) = .07, *p* = .96; RSI (reactive strength index) *H*(2) = .94, *p* = .63 and Sprint time *H*(2) =1.35, *p* = .51; *p* > .05 (Table 4.8).

Table 4.8

Kruskal Wallis Test Results for Intergroup Differences in Pre-Test Values of Sprint and Jump Parameters

Variable	***Group***	***n***	***Mean Rank***	***sd***	***X^2***	***p***
CMJ (cm)	PTH	8	11.88	2	.06	.97
	PTN	7	11.64			
	Control	8	12.44			
SJ (cm)	PTH	8	11.19	2	.20	.91
	PTN	7	12.14			
	Control	8	12.69			
DJ (cm)	PTH	8	10.13	2	1.09	.58
	PTN	7	13.71			
	Control	8	12.38			
DJ (ms)	PTH	8	12.13	2	.07	.96
	PTN	7	12.43			
	Control	8	11.50			
RSI (m/sec)	PTH	8	10.19	2	.94	.63
	PTN	7	13.43			
	Control	8	12.56			
Sprint (ms)	PTH	8	14.25	2	1.35	.51
	PTN	7	10.86			
	Control	8	10.75			

$p > .05$

No significant difference was found, in post-test results, among the three groups in CMJ (countermovement jump height) (cm) $H(2) = 2.57$, $p = .28$; in SJ (squat jump height) (cm) $H(2) = 3.03$, $p = .22$; in DJ (drop jump height) (cm) $H(2) = 4.97$, $p = .08$; in DJ (drop jump ground contact time) (ms) $H(2) = 4.35$, $p = .11$; in RSI (reactive strength index) (m/sec) $H(2) = 3.76$, $p = .15$; and in sprint time (ms) $H(2) = 2.91$, $p = .23$; $p > .05$ (Table 4.9).

According to the pre-test and post-test comparison of PTH group, plyometric training in normobaric hypoxia significantly increased the values of CMJ (countermovement jump height) (cm) ($z = -2.52$, $p = .01$, $r = -.63$), SJ (squat jump height) (cm) ($z = -2.52$, $p = .01$, $r = -.63$), DJ (drop jump height) (cm) ($z = -2.52$, $p = .01$, $r = -.63$), DJ (drop jump ground contact time) (ms) ($z = -2.03$, $p = .04$, $r = -.51$), RSI (reactive strength index) (m/sec) ($z = -2.10$, $p = .04$, $r = -.53$) and decreased the sprint value (ms) ($z = -2.52$, $p = .01$, $r = -.63$) between pre- and post-test results, $p < .05$ (Table 4.10).

Table 4.9

Kruskal Wallis Test Results for Intergroup Differences in Post-Test Values of Sprint and Jump Parameters

Variable	***Group***	***n***	***Mean Rank***	***sd***	***X^2***	***p***
CMJ (cm)	PTH	8	14.69	2	2.57	.28
	PTN	7	12.07			
	Control	8	9.25			
SJ (cm)	PTH	8	14.63	2	3.03	.22
	PTN	7	12.64			
	Control	8	8.81			
DJ (cm)	PTH	8	14.31	2	4.97	.08
	PTN	7	14.29			
	Control	8	7.69			
DJ (ms)	PTH	8	15.63	2	4.35	.11
	PTN	7	8.36			
	Control	8	11.56			
RSI (m/sec)	PTH	8	12.56	2	3.76	.15
	PTN	7	15.29			
	Control	8	8.56			
Sprint (ms)	PTH	8	10.75	2	2.91	.23
	PTN	7	9.71			
	Control	8	15.25			

$p > .05$

Table 4.10

Intragroup Comparison of Sprint and Jump Parameters in PTH Group

Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
CMJ (cm)	Negative Ranks	0	.00	.00	-2.52	**.01***	-.63
	Positive Ranks	8	4.50	36			
	Ties	0	-	-			
SJ (cm)	Negative Ranks	0	.00	.00	-2.52	**.01***	-.63
	Positive Ranks	8	4.50	36			
	Ties	0	-	-			
DJ (cm)	Negative Ranks	0	.00	.00	-2.52	**.01***	-.63
	Positive Ranks	8	4.50	36			
	Ties	0	-	-			
DJ (ms)	Negative Ranks	2	1.75	3.50	-2.03	**.04***	-.51
	Positive Ranks	6	5.42	32.50			
	Ties	0	-	-			
RSI (m/sec)	Negative Ranks	2	1.50	3	-2.10	**.04***	-.53
	Positive Ranks	6	5.50	33			
	Ties	0	-	-			
Sprint (ms)	Negative Ranks	8	4.50	36	-2.52	**.01***	-.63
	Positive Ranks	0	.00	.00			
	Ties	0	-	-			

***** $p < .05$

According to the comparison of pre and post-test results of PTN group, plyometric training in normoxia significantly increased CMJ (countermovement jump height) (cm) (*z* = -2.37, *p* = .02, *r* = -.63) and decreased sprint time (ms) (*z* = -2.20, *p* = .03, *r* = -.59) *p* < .05. However, the differences in SJ (squat jump height) (cm) (*z* = -1.86, *p* = .06, *r* = -.50), DJ (drop jump height) (cm) (*z* = -1.69, *p* = .09, *r* = -.45), DJ (drop jump ground contact time) (ms) (*z* = -.34, *p* = .74, *r* = -.09) and RSI (reactive strength index) (m/sec) (*z* = -.85, *p* = .40, *r* = -.23) were not statistically significant between pre- and post-test results, *p* > .05 (Table 4.11).

In terms of the pre and post-test results for the Control group, there was no significant difference in CMJ (countermovement jump height) (cm) (*z* = - 1.40, *p* = .16, *r* = -.35), in SJ (squat jump height) (cm) (*z* = -.14, *p* = .89, *r* = -.04), in DJ (drop jump height) (cm) (*z* = -.56, *p* = .58, *r* = -.14), in DJ (drop jump ground contact time) (ms) (*z* = -.98, *p* = .33, *r* = -.25), in RSI (reactive strength index) (m/sec) (*z* = -.84, *p* = .40, *r* = -.21) and in sprint time (ms) (*z* = -.14, *p* = .89, *r* = -.04) between pre- and post-test results, *p* > .05 (Table 4.12).

Table 4.11

Intragroup Comparison of Sprint and Jump Parameters in PTN Group

Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
CMJ (cm)	Negative Ranks	0	.00	.00	-2.37	**.02***	-.63
	Positive Ranks	7	4	28			
	Ties	0	-	-			
SJ (cm)	Negative Ranks	1	3	3	-1.86	.06	-.50
	Positive Ranks	6	4.17	25			
	Ties	0	-	-			
DJ (cm)	Negative Ranks	1	4	4	-1.69	.09	-.45
	Positive Ranks	6	4	24			
	Ties	0	-	-			
DJ (ms)	Negative Ranks	4	4	16	-.34	.74	-.09
	Positive Ranks	3	4	12			
	Ties	0	-	-			
RSI (m/sec)	Negative Ranks	2	4.50	9	-.85	.40	-.23
	Positive Ranks	5	3.80	19			
	Ties	0	-	-			
Sprint (ms)	Negative Ranks	6	4.50	27	-2.20	**.03***	-.59
	Positive Ranks	1	1	1			
	Ties	0	-	-			

*****p < .05

Table 4.12

Intragroup Comparison of Sprint and Jump Parameters in Control Group

Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
CMJ (cm)	Negative Ranks	2	4	8	-1.40	.16	-.35
	Positive Ranks	6	4.67	28			
	Ties	0	-	-			
SJ (cm)	Negative Ranks	3	5.67	17	-.14	.89	-.04
	Positive Ranks	5	3.80	19			
	Ties	0	-	-			
DJ (cm)	Negative Ranks	4	5.50	22	-.56	.58	-.14
	Positive Ranks	4	3.50	14			
	Ties	0	-	-			
DJ (ms)	Negative Ranks	3	3.67	11	-.98	.33	-.25
	Positive Ranks	5	5	25			
	Ties	0	-	-			
RSI (m/sec)	Negative Ranks	5	4.80	24	-.84	.40	-.21
	Positive Ranks	3	4	12			
	Ties	0	-	-			
Sprint (ms)	Negative Ranks	4	4.25	17	-.14	.89	-.04
	Positive Ranks	4	4.75	19			
	Ties	0	-	-			

$p > .05$

4.3. Wingate Test Results

Intragroup mean, standard deviation and percentage changes of Wingate test variables were stated in Table 4.13. Peak power showed an increase of 7.72%, 6.09% and 1.39% in the groups of PTH (*M* = 784.22, *SD* = 170 to *M* = 844.75, *SD* = 169.62), PTN (*M* = 757.67, *SD* = 84.69 to *M* = 803.81, *SD* = 65.42) and Control (*M* = 774.64, *SD* = 124.91 to *M* = 763.85, *SD* = 119.36), respectively. As for the relative peak power, there was an increase by 7.89%, 7.05% and 1.16% in the groups of PTH (*M* = 11.28, *SD* = 1.32 to *M* = 12.17, *SD* = 1.13), PTN (*M* = 11.49, *SD* = .78 to *M* = 12.30, *SD* = 1.08) and Control (*M* = 11.21, *SD* = .61 to *M* = 11.34, *SD* = 1.11), respectively. While 4.32% increase in PTH (*M* = 570.28, *SD* = 126.29 to *M* = 594.92, *SD* = 135.10) and 8.32% increase in PTN (*M* = 520.02, *SD* = 83.85 to *M* = 563.29, *SD* = 58.33) were seen in the average power, a 0.47% reduction in the average power was found in Control group (*M* = 553.47, *SD* = 90.82 to *M* = 550.89, *SD* = 82.35). Relative average power demonstrated a 4.41% increase in PTH group (*M* = 8.17, *SD* = .73 to *M* = 8.53, *SD* = .70), a 10.06% increase in PTN group (*M* = 7.85, *SD* = .61 to *M* = 8.64, *SD* = .73) and a 1.87% increase in Control group (*M* = 8.03, *SD* = .68 to *M* = 8.18, *SD* = .64) (Table 4.13).

Table 4.13
Intragroup Mean, Standard Deviation and Percentage Changes of Wingate Test Variables

Variable	***Group***	***n***	***Pre-test M±SD***	***Post-test M±SD***	***Change (%)***
Peak Power (w)	PTH	8	784.22±170	844.75±169.62	7.72
	PTN	7	757.67±84.69	803.81±65.42	6.09
	Control	8	774.64±124.91	763.85±119.36	1,39
Relative Peak Power (w/kg)	PTH	8	11.28±1.32	12.17±1.13	7.89
	PTN	7	11.49±.78	12.30±1.08	7.05
	Control	8	11.21±.61	11.34±1.11	1.16
Average Power (w)	PTH	8	570.28±126.29	594.92±135.10	4.32
	PTN	7	520.02±83.85	563.29±58.33	8.32
	Control	8	553.47±90.82	550.89±82.35	0.47
Relative Average Power (w/kg)	PTH	8	8.17±.73	8.53±.70	4.41
	PTN	7	7.85±.61	8.64±.73	10.06
	Control	8	8.03±.68	8.18±.64	1.87
Min. Power (w)	PTH	8	336.05±116.59	357.21±101.24	6.30
	PTN	7	308.07±58.85	316.60±50.50	2.77
	Control	8	301.52±40.87	298.97±32.14	0.85
Relative Min. Power (w/kg)	PTH	8	4.74±1.27	5.09±.75	7.38
	PTN	7	4.65±.62	4.85±.61	4.30
	Control	8	4.41±.58	4.50±.73	2.04
Power Drop (%)	PTH	8	57.55±11.74	57.23±6.40	0.56
	PTN	7	59.51±4.58	60.22±4.59	1.19
	Control	8	60.52±5.75	59.80±8.74	1.19
Decline in Power (w)	PTH	8	400.98±127.28	437.60±66	9.13
	PTN	7	431.29±39.97	452.32±38.15	4.88
	Control	8	447.73±123.40	430.75±133.41	3.79

For the value of Min.power, while 6.30% increment in PTH group (*M* = 336.05, *SD* = 116.59 to *M* = 357.21, *SD* = 101.24) and 2.77% rise in PTN group (*M* = 308.07, *SD* = 58.85 to *M* = 316.60, *SD* = 50.50) were detected, 0.85% decrease was observed in Control group (*M* = 301.52, *SD* = 40.87 to *M* = 298.97, *SD* = 32.14). 7.38%, 4.30%, 2.04% increases were observed in Realtive Min.power in the groups of PTH (*M* = 4.74, *SD* = 1.27 to *M* = 5.09, *SD* = .75), PTN (*M* = 4.65, *SD* = .62 to *M* = 4.85, *SD* = .61) and Control (*M* = 4.41, *SD* = .58 to *M* = 4.50, *SD* = .73), respectively. Power drop (%) showed 0.56% reduction in PTH group (*M* = 57.55, *SD* = 11.74 to *M* = 57.23, *SD* = 6.40), 1.19% increase in PTN group (*M* = 59.51, *SD* = 4.58 to *M* = 60.22, *SD* = 4.59) and 1.19% decrease in Control group

(*M* = 60.52, *SD* = 5.75 to *M* = 59.80, *SD* = 8.74). As for the Decline in power, while there was a 9.13% increase in PTH group (*M* = 400.98, *SD* = 127.28 to *M* = 437.60, *SD* = 66) and 4.88% rise in PTN group (*M* = 431.29, *SD* = 39.97 to *M* = 452.32, *SD* = 38.15), there was a 3.79% decrease in Control group (*M* = 447.73, *SD* = 123.40 to *M* = 430.75, *SD* = 133.41) (Table 4.13). According to pre-test results of Kruskal Wallis Test, no significant difference was found among the groups in Peak Power *H*(2) = .12, *p* = .94; Relative Peak Power *H*(2) = .73, *p* = .70; Average Power *H*(2) = .92, *p* = .63; Relative Average Power *H*(2) = .92, *p* = .63; Min. Power *H*(2) = 1.36, *p* = .51; Relative Min. Power *H*(2) = 1.31, *p* = .52; Power Drop *H*(2) = 1.46, *p* = .48; and Decline in Power *H*(2) = .81, *p* = .67; *p* > .05 (Table 4.14).

Table 4.14

Intergroup Comparisons of Wingate Test results in Pre-test

Variable	***Group***	***n***	***Mean Rank***	***sd***	***X^2***	***p***
Peak Power (w)	PTH	8	12.13	2	.12	.94
	PTN	7	11.29			
	Control	8	12.50			
Relative Peak Power (w/kg)	PTH	8	11.50	2	.73	.70
	PTN	7	13.79			
	Control	8	10.94			
Average Power (w)	PTH	8	13.25	2	.92	.63
	PTN	7	10.00			
	Control	8	12.50			
Relative Average Power (w/kg)	PTH	8	13.50	2	.92	.63
	PTN	7	10.14			
	Control	8	12.13			
Min. Power (w)	PTH	8	14.25	2	1.36	.51
	PTN	7	11.00			
	Control	8	10.63			
Relative Min. Power (w/kg)	PTH	8	14.00	2	1.31	.52
	PTN	7	11.86			
	Control	8	10.13			
Power Drop (%)	PTH	8	9.75	2	1.46	.48
	PTN	7	12.57			
	Control	8	13.75			
Decline in Power (w)	PTH	8	10.00	2	.81	.67
	PTN	7	11.71			
	Control	8	13.00			

p >.05

According to post-test results of Kruskal Wallis Test, no significant difference was found among the three groups in Peak Power (w) *H*(2) = .85, *p* = .65; Relative

Peak Power (w/kg) *H*(2) = 3.54, *p* = .17; Average Power (w) *H*(2) = .54, *p* = .76; Relative Average Power (w/kg) *H*(2) = 1.93, *p* = .38; Min. Power (w) *H*(2) = 1.35, *p* = .51; Relative Min. Power (w/kg) *H*(2) = 3.12, *p* = .21; Power Drop (%) *H*(2) = 1.35, *p* = .51; and Decline in Power (w) *H*(2) = .07, *p* = .97; *p* > .05 (Table 4.15).

Table 4.15

Intergroup Comparisons of Wingate Test results in Post-test

Variable	***Group***	***n***	***Mean Rank***	***sd***	***X²***	***p***
Peak Power (w)	PTH	8	13.50	2	.85	.65
	PTN	7	12.14			
	Control	8	10.38			
Relative Peak Power (w/kg)	PTH	8	13.63	2	3.54	.17
	PTN	7	14.29			
	Control	8	8.38			
Average Power (w)	PTH	8	13.25	2	.54	.76
	PTN	7	12.00			
	Control	8	10.75			
Relative Average Power (w/kg)	PTH	8	13.38	2	1.93	.38
	PTN	7	13.50			
	Control	8	9.31			
Min. Power (w)	PTH	8	14.13	2	1.35	.51
	PTN	7	11.57			
	Control	8	10.25			
Relative Min. Power (w/kg)	PTH	8	14.63	2	3.12	.21
	PTN	7	12.71			
	Control	8	8.75			
Power Drop (%)	PTH	8	9.75	2	1.35	.51
	PTN	7	13.29			
	Control	8	13.13			
Decline in Power (w)	PTH	8	11.50	2	.07	.97
	PTN	7	12.29			
	Control	8	12.25			

p >.05

As for the pre-test and post-test comparison of PTH group, plyometric training in normobaric hypoxia significantly increased the Peak Power (w) (*z* = -2.38, *p* = .02, *r* = -.60) and Relative Peak Power (w/kg) (*z* = -1.96, *p* = .05, *r* = -.49), *p* ≤ .05, however, showed non-significant increase in Average Power (w) (*z* = -1.82, *p* = .07, *r* = -.46), Relative Average Power (w/kg) (*z* = -1.82, *p* = .07, *r* = -.46), Min. Power (w) (*z* = -.98, *p* = .33, *r* = -.25), Relative Min. Power (w/kg) (*z* = -1.26, *p* = .21, *r* = -.32), Decline in Power (w) (*z* = -1.12, *p* = .26, *r* = -.28) and non-significant decrease in Power Drop (%) (*z* = -.42, *p* = .67, *r* = -.11) between pre- and post-test results, *p* > .05 (Table 4.16).

Table 4.16
Intragroup Comparison of Wingate Test results in PTH Group

Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Peak Power (w)	Negative Ranks	1	1	1	-2.38	**.02***	-.60
	Positive Ranks	7	5	35			
	Ties	0	-	-			
Relative Peak Power (w/kg)	Negative Ranks	1	4	4	-1.96	**.05***	-.49
	Positive Ranks	7	4.57	32			
	Ties	0	-	-			
Average Power (w)	Negative Ranks	2	2.50	5	-1.82	.07	-.46
	Positive Ranks	6	5.17	31			
	Ties	0	-	-			
Relative Average Power (w/kg)	Negative Ranks	2	2.50	5	-1.82	.07	-.46
	Positive Ranks	6	5.17	31			
	Ties	0	-	-			
Min. Power (w)	Negative Ranks	3	3.67	11	-.98	.33	-.25
	Positive Ranks	5	5	25			
	Ties	0	-	-			
Relative Min. Power (w/kg)	Negative Ranks	2	4.50	9	-1.26	.21	-.32
	Positive Ranks	6	4.50	27			
	Ties	0	-	-			
Power Drop (%)	Negative Ranks	4	5.25	21	-.42	.67	-.11
	Positive Ranks	4	3.75	15			
	Ties	0	-	-			
Decline in Power (w)	Negative Ranks	4	2.50	10	-1.12	.26	-.28
	Positive Ranks	4	6.50	26			
	Ties	0	-	-			

*p ≤.05

In terms of the pre-test and post-test comparison of PTN group, plyometric training in normoxia made a significant difference in Peak Power (w) (*z* = -2.20, *p* = .03, *r* = -.59), Relative Peak Power (w/kg) (*z* = -2.37, *p* = .02, *r* = -.63), and Relative Average Power (w/kg) (*z* = -2.37, *p* = .02, *r* = -.63) *p* < .05 (Table 4.17).

However, plyometric training in normoxia elicited non-significant increase in Average Power (w) (*z* = -1.86, *p* = .06, *r* = -.50), Min. Power (w) (*z* = -.51, *p* = .61, *r* = -.14), Relative Min. Power (w/kg) (*z* = -.85, *p* = .40, *r* = -.23), Power Drop (%) (*z* = -.34, *p* = .74, *r* = -.09) and Decline in Power (w) (*z* = -.68, *p* = .50, *r* = -.18) between pre- and post-test results, *p* > .05 (Table 4.17).

Table 4.17
Intragroup Comparison of Wingate Test results in PTN Group

Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Peak Power (w)	Negative Ranks	1	1	1	-2.20	**.03***	-.59
	Positive Ranks	6	4.50	27			
	Ties	0	-	-			
Relative Peak Power (w/kg)	Negative Ranks	0	.00	.00	-2.37	**.02***	-.63
	Positive Ranks	7	4	28			
	Ties	0	-	-			
Average Power (w)	Negative Ranks	2	1.50	3	-1.86	.06	-.50
	Positive Ranks	5	5	25			
	Ties	0	-	-			
Relative Average Power (w/kg)	Negative Ranks	0	.00	.00	-2.37	**.02***	-.63
	Positive Ranks	7	4	28			
	Ties	0	-	-			
Min. Power (w)	Negative Ranks	4	2.75	11	-.51	.61	-.14
	Positive Ranks	3	5.67	17			
	Ties	0	-	-			
Relative Min. Power (w/kg)	Negative Ranks	3	3	9	-.85	.40	-.23
	Positive Ranks	4	4.75	19			
	Ties	0	-	-			
Power Drop (%)	Negative Ranks	3	4	12	-.34	.74	-.09
	Positive Ranks	4	4	16			
	Ties	0	-	-			
Decline in Power (w)	Negative Ranks	3	3.33	10	-.68	.50	-.18
	Positive Ranks	4	4.50	18			
	Ties	0	-	-			

$*p \leq .05$

As is seen in Table 4.18, no significant difference was found in Peak Power (w) ($z = -.56$, $p = .58$, $r = -.14$), Relative Peak Power (w/kg) ($z = -.70$, $p = .48$, $r = -.18$), Average Power (w) ($z = -.14$, $p = .89$, $r = -.04$), Relative Average Power (w/kg) ($z = -.84$, $p = .40$, $r = -.21$), $p > .05$, between pre- and post-test results of the Control group (Table 4.18).

Also, there were no significant difference between pre- and post-test results in Min. Power (w) ($z = -.84$, $p = .40$, $r = -.21$), Relative Min. Power (w/kg) ($z = -1.12$, $p = .26$, $r = -.28$), Power Drop (%) ($z = -.98$, $p = .33$, $r = -.25$) and Decline in Power (w) ($z = -.34$, $p = .74$, $r = -.09$), $p > .05$, in the Control group (Table 4.18).

Table 4.18

Intragroup Comparison of Wingate Test results in Control Group

Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Peak Power (w)	Negative Ranks	5	4.40	22	-.56	.58	-.14
	Positive Ranks	3	4.67	14			
	Ties	0	-	-			
Relative Peak Power (w/kg)	Negative Ranks	3	4.33	13	-.70	.48	-.18
	Positive Ranks	5	4.60	23			
	Ties	0	-	-			
Average Power (w)	Negative Ranks	4	4.75	19	-.14	.89	-.04
	Positive Ranks	4	4.25	17			
	Ties	0	-	-			
Relative Average Power (w/kg)	Negative Ranks	3	4	12	-.84	.40	-.21
	Positive Ranks	5	4.80	24			
	Ties	0	-	-			
Min. Power (w)	Negative Ranks	2	6	12	-.84	.40	-.21
	Positive Ranks	6	4	24			
	Ties	0	-	-			
Relative Min. Power (w/kg)	Negative Ranks	2	5	10	-1.12	.26	-.28
	Positive Ranks	6	4.33	26			
	Ties	0	-	-			
Power Drop (%)	Negative Ranks	6	4.17	25	-.98	.33	-.25
	Positive Ranks	2	5.50	11			
	Ties	0	-	-			
Decline in Power (w)	Negative Ranks	5	3.20	16	-.34	.74	-.09
	Positive Ranks	2	6	12			
	Ties	0	-	-			

$p > .05$

4.4. Isokinetic Test Results

Intragroup mean, standard deviation and percentage changes of isokinetic strength test variables at the speed of 60°/sec for the right and left leg evaluations were expressed in Table 4.19.

Flex. maxTorque demonstrated 15.69% increase in PTH group (*M* = 119.50, *SD* = 23.11 to *M* = 138.25, *SD* = 19.91), 11.93% rise in PTN group (*M* = 112.57, *SD* = 25.26 to *M* = 126, *SD* = 18.71) and 1.52% decrease in Control group (*M* = 114.37, *SD* = 27.90 to *M* = 112.63, *SD* = 17.11) (Table 4.19).

In Ext. maxTorque, a 1.85% increment in PTH group (*M* = 216.38, *SD* = 43.53 to *M* = 220.38, *SD* = 35.75), a 3.21% increase in PTN group (*M* = 191.29, *SD* = 26.92 to *M* = 197.43, *SD* = 31.76) and a 6.91% decrease in Control group (*M* =

206.13, *SD* = 33.28 to *M* = 191.88, *SD* = 30.27) were observed (Table 4.19). As for the Flex. maxTorque/weight value, a 13.71% increase in PTH group (*M* = 1.75, *SD* = .42 to *M* = 1.99, *SD* = .26), a 6.59% reduction in PTN group (*M* = 1.67, *SD* = .47 to *M* = 1.56, *SD* = .67) and a 1.22% increase in Control group (*M* = 1.64, *SD* = .39 to *M* = 1.66, *SD* = .31) were detected (Table 4.19). Ext. maxTorque/weight showed 2.60% rise in PTH group (*M* = 3.08, *SD* = .38 to *M* = 3.16, *SD* = .21), 14.29% decrease in PTN group (*M* = 2.80, *SD* = .22 to *M* = 2.40, *SD* = .91) and 3.38% reduction in Control group (*M* = 2.96, *SD* = .39 to *M* = 2.86, *SD* = .43) (Table 4.19). 18%, 13.35%, 0.61% increases were found in Flex. peak power in the groups of PTH (*M* = 87.50, *SD* = 20.10 to *M* = 103.25, *SD* = 14.24), PTN (*M* = 81.29, *SD* = 21.29 to *M* = 92.14, *SD* = 15.27) and Control group (*M* = 81.88, *SD* = 21.14 to *M* = 82.38, *SD* = 15.83), respectively, (Table 4.19). In Ext. peak power value, there was a 3.13% increase in PTH (*M* = 139.63, *SD* = 25.60 to *M* = 144, *SD* = 24.41), a 3.76% increment in PTN (*M* = 121.43, *SD* = 10.36 to *M* = 126, *SD* = 19) and a 2.77% decline in Control group (*M* = 125.87, *SD* = 16.79 to *M* = 122.38, *SD* = 13.53) (Table 4.19). Flex./ext. showed increase by 12.5%, 6.67% and 9.09% in the groups of PTH (*M* = .56, *SD* = .12 to *M* = .63, *SD* = .08), PTN (*M* = .60, *SD* = .15 to *M* = .64, *SD* = .08) and Control (*M* = .55, *SD* = .09 to *M* = .60, *SD* = .13), respectively, (Table 4.19).

The above results belong to the right leg measurements. As for the left leg results, a 3.39% increase in PTH (*M* = 125.38, *SD* = 28.76 to *M* = 129.63, *SD* = 15.88), a 1.62% rise in PTN (*M* = 115, *SD* = 26.46 to *M* = 116.86, *SD* = 9.79) and a 8.36% decline in Control group (*M* = 125.63, *SD* = 16.47 to *M* = 115.13, *SD* = 12.14) were observed in Flex. maxTorque (Table 4.19).

The value of Ext. maxTorque demonstrated a 0.59% decline in PTH (*M* = 213, *SD* = 52.96 to *M* = 211.75, *SD* = 41.48), a 1.10% increment in PTN (*M* = 181.57, *SD* = 19.97 to *M* = 183.57, *SD* = 19.78) and a 15.44% reduction in Control group (*M* = 201.63, *SD* = 28.59 to *M* = 170.50, *SD* = 42.86) (Table 4.19). In Flex. maxTorque/weight, while there was a 2.20% increase in PTH (*M* = 1.82, *SD* = .42 to *M* = 1.86, *SD* = .19), there was a 16.57% decrease in PTN (*M* = 1.69, *SD* = .38 to *M* = 1.41, *SD* = .59) and a 6.08% decline in Control group (*M* = 1.81, *SD* = .24

to *M* = 1.70, *SD* = .19) (Table 4.19). Ext. maxTorque/weight presented decrease by 0.33%, 16.85% and 12.41% in the groups of PTH (*M* = 3.03, *SD* = .52 to *M* = 3.02, *SD* = .27), PTN (*M* = 2.67, *SD* = .25 to *M* = 2.22, *SD* = .80) and Control (*M* = 2.90, *SD* = .32 to *M* = 2.54, *SD* = .63), respectively, (Table 4.19). In Flex. peak power, while a 6.22% increase in PTH (*M* = 92.38, *SD* = 28.29 to *M* = 98.13, *SD* = 12.28) and a 2.20% rise in PTN (*M* = 84.57, *SD* = 18.96 to *M* = 86.43, *SD* = 9.43) were found, a 7.22% decrease was observed in Control group (*M* = 91.75, *SD* = 11.83 to *M* = 85.13, *SD* = 13.82) (Table 4.19). As for the Ext.peak power, there was a 2.83% increment in PTH (*M* = 137, *SD* = 32.10 to *M* = 140.88, *SD* = 23.55), 3.72% rise in PTN (*M* = 111.43, *SD* = 15.04 to *M* = 115.57, *SD* = 13.78) and 10.10% decline in Control group (*M* = 121.25, *SD* = 18.99 to *M* = 109, *SD* = 23.68) (Table 4.19). Flex./ext. showed a 3.33% increase in PTH (*M* = .60, *SD* = .12 to *M* = .62, *SD* = .07), a 1.59% increase in PTN (*M* = .63, *SD* = .11 to *M* = .64, *SD* = .08) and a 15.87% decrease in Control group (*M* = .63, *SD* = .09 to *M* = .73, *SD* = .26) (Table 4.19). According to the pre-test results of Kruskal Wallis Test for the isokinetic strength at the speed of 60°/sec, no significant difference was found among the groups in Flex.maxTorque *H*(2) = .71, *p* = .70; Ext.maxTorque *H*(2) = 1.22, *p* = .54; Flex.maxTorque/weight *H*(2) = .65, *p* = .72; Ext. maxTorque/weight *H*(2) = 2.76, *p* = .25; Flex.peak power *H*(2) = 1.12, *p* = .57; Ext.peak power *H*(2) = 2.38, *p* = .31; and Flex./ext. *H*(2) = .71, *p* = .70 in right leg measurements (Table 4.20).

As for the left leg, there was no significant difference among the groups in Flex.maxTorque *H*(2) = 1.23, *p* = .54; Ext.maxTorque *H*(2) = 2.59, *p* = .27; Flex.maxTorque/weight *H*(2) = .55, *p* = .76; Ext. maxTorque/weight *H*(2) = 3.23, *p* = .20; Flex.peak power *H*(2) = 1.18, *p* = .56; Ext.peak power *H*(2) = 2.51, *p* = .29; and Flex./ext. *H*(2) = .28, *p* = .87; *p*> .05 (Table 4.20).

In regard to the post-test results of Kruskal Wallis Test for the isokinetic strength at the speed of 60°/sec, in right leg measurements, while there was no significant difference among the groups in Flex.maxTorque *H*(2) = 5.31, *p* = .07; Ext.maxTorque *H*(2) = 2.25, *p* = .33; Flex.maxTorque/weight *H*(2) = 3.86, *p* = .15; Ext.maxTorque/weight *H*(2) = 3.60, *p* = .17; Ext.peak power *H*(2) = 3.75, *p* =

.15; and Flex./ext. $H(2) = .38$, $p = .83$; $p > .05$, there was a significant difference in Flex.peak power $H(2) = 7.00$, $p = .03$; $p < .05$ (Table 4.21).

Table 4.19

Intragroup Mean, Standard Deviation and Percentage Changes of Isokinetic Test Variables at 60°/sec

	Variable	***Group***	***n***	***Pre-test M±SD***	***Post-test M±SD***	***Change (%)***
Right	Flex. maxTorque(Nm)	PTH	8	119.50±23.11	138.25±19.91	15.69
		PTN	7	112.57±25.26	126±18.71	11.93
		Control	8	114.37±27.90	112.63±17.11	1.52
	Ext. maxTorque(Nm)	PTH	8	216.38±43.53	220.38±35.75	1.85
		PTN	7	191.29±26.92	197.43±31.76	3.21
		Control	8	206.13±33.28	191.88±30.27	6.91
	Flex. maxTorque/weight	PTH	8	1.75±.42	1.99±.26	13.71
		PTN	7	1.67±.47	1.56±.67	6.59
		Control	8	1.64±.39	1.66±.31	1.22
	Ext. maxTorque/weight	PTH	8	3.08±.38	3.16±.21	2.60
		PTN	7	2.80±.22	2.40±.91	14.29
		Control	8	2.96±.39	2.86±.43	3.38
	Flex. peak power (W)	PTH	8	87.50±20.10	103.25±14.24	18
		PTN	7	81.29±21.29	92.14±15.27	13.35
		Control	8	81.88±21.14	82.38±15.83	0.61
	Ext. peak power (W)	PTH	8	139.63±25.60	144±24.41	3.13
		PTN	7	121.43±10.36	126±19	3.76
		Control	8	125.87±16.79	122.38±13.53	2.77
	Flex./ext.	PTH	8	.56±.12	.63±.08	12.5
		PTN	7	.60±.15	.64±.08	6.67
		Control	8	.55±.09	.60±.13	9.09
Left	Flex. maxTorque(Nm)	PTH	8	125.38±28.76	129.63±15.88	3.39
		PTN	7	115±26.46	116.86±9.79	1.62
		Control	8	125.63±16.47	115.13±12.14	8.36
	Ext. maxTorque(Nm)	PTH	8	213±52.96	211.75±41.48	0.59
		PTN	7	181.57±19.97	183.57±19.78	1.10
		Control	8	201.63±28.59	170.50±42.86	15.44
	Flex. maxTorque/weight	PTH	8	1.82±.42	1.86±.19	2.20
		PTN	7	1.69±.38	1.41±.59	16.57
		Control	8	1.81±.24	1.70±.19	6.08
	Ext. maxTorque/weight	PTH	8	3.03±.52	3.02±.27	0.33
		PTN	7	2.67±.25	2.22±.80	16.85
		Control	8	2.90±.32	2.54±.63	12.41
	Flex. peak power (W)	PTH	8	92.38±28.29	98.13±12.28	6.22
		PTN	7	84.57±18.96	86.43±9.43	2.20
		Control	8	91.75±11.83	85.13±13.82	7.22
	Ext. peak power (W)	PTH	8	137±32.10	140.88±23.55	2.83
		PTN	7	111.43±15.04	115.57±13.78	3.72
		Control	8	121.25±18.99	109±23.68	10.10
	Flex./ext.	PTH	8	.60±.12	.62±.07	3.33
		PTN	7	.63±.11	.64±.08	1.59
		Control	8	.63±.09	.73±.26	15.87

Flex. : Flexion, **Ext.** : Extension

Table 4.20

Intergroup Comparisons of Isokinetic Test results at 60°/sec in Pre-test

	Variable	***Group***	*n*	***Mean Rank***	*sd*	X^2	*p*
Right	Flex. maxTorque(Nm)	PTH	8	12.94	2	.71	.70
		PTN	7	10.21			
		Control	8	12.63			
	Ext. maxTorque(Nm)	PTH	8	12.94	2	1.22	.54
		PTN	7	9.64			
		Control	8	13.13			
	Flex. maxTorque/weight	PTH	8	13.13	2	.65	.72
		PTN	7	12.43			
		Control	8	10.50			
	Ext. maxTorque/weight	PTH	8	13.81	2	2.76	.25
		PTN	7	8.50			
		Control	8	13.25			
	Flex. peak power (W)	PTH	8	13.88	2	1.12	.57
		PTN	7	10.21			
		Control	8	11.69			
	Ext. peak power (W)	PTH	8	14.75	2	2.38	.31
		PTN	7	9.43			
		Control	8	11.50			
	Flex./ext.	PTH	8	12.25	2	.71	.70
		PTN	7	13.43			
		Control	8	10.50			
Left	Flex. maxTorque(Nm)	PTH	8	12.88	2	1.23	.54
		PTN	7	9.64			
		Control	8	13.19			
	Ext. maxTorque(Nm)	PTH	8	13.69	2	2.59	.27
		PTN	7	8.57			
		Control	8	13.31			
	Flex. maxTorque/weight	PTH	8	12.75	2	.55	.76
		PTN	7	10.43			
		Control	8	12.63			
	Ext. maxTorque/weight	PTH	8	14.13	2	3.23	.20
		PTN	7	8.21			
		Control	8	13.19			
	Flex. peak power (W)	PTH	8	12.44	2	1.18	.56
		PTN	7	9.79			
		Control	8	13.50			
	Ext. peak power (W)	PTH	8	14.63	2	2.51	.29
		PTN	7	9.07			
		Control	8	11.94			
	Flex./ext.	PTH	8	11.25	2	.28	.87
		PTN	7	11.71			
		Control	8	13.00			

$p > .05$

Table 4.21

Intergroup Comparisons of Isokinetic Test results at 60°/sec in Post-test

	Variable	***Group***	***n***	***Mean Rank***	***sd***	***X^2***	***p***
Right	Flex. maxTorque(Nm)	PTH	8	15.63	2	5.31	.07
		PTN	7	12.57			
		Control	8	7.88			
	Ext. maxTorque(Nm)	PTH	8	14.88	2	2.25	.33
		PTN	7	10.86			
		Control	8	10.13			
	Flex. maxTorque/weight	PTH	8	15.75	2	3.86	.15
		PTN	7	10.50			
		Control	8	9.56			
	Ext. maxTorque/weight	PTH	8	15.50	2	3.60	.17
		PTN	7	9.14			
		Control	8	11.00			
	Flex. peak power (W)	PTH	8	16.44	2	7.00	**.03***
		PTN	7	12.07			
		Control	8	7.50			
	Ext. peak power (W)	PTH	8	15.69	2	3.75	.15
		PTN	7	10.64			
		Control	8	9.50			
	Flex./ext.	PTH	8	12.25	2	.38	.83
		PTN	7	13.00			
		Control	8	10.88			
Left	Flex. maxTorque(Nm)	PTH	8	15.75	2	3.82	.15
		PTN	7	10.43			
		Control	8	9.63			
	Ext. maxTorque(Nm)	PTH	8	15.69	2	3.66	.16
		PTN	7	10.36			
		Control	8	9.75			
	Flex. maxTorque/weight	PTH	8	15.69	2	3.99	.14
		PTN	7	9.00			
		Control	8	10.94			
	Ext. maxTorque/weight	PTH	8	17.13	2	7.80	**.02***
		PTN	7	7.64			
		Control	8	10.69			
	Flex. peak power (W)	PTH	8	15.56	2	3.42	.18
		PTN	7	10.29			
		Control	8	9.94			
	Ext. peak power (W)	PTH	8	16.69	2	5.97	**.05***
		PTN	7	10.07			
		Control	8	9.00			
	Flex./ext.	PTH	8	10.63	2	.52	.77
		PTN	7	12.50			
		Control	8	12.94			

*$p \leq .05$

Table 4.22

Mann–Whitney Test Results between Hypoxia-Normoxia groups at 60°/sec

	Variable	***Group***	***n***	***Mean Rank***	***Sum of Ranks***	***U***	***z***	***p***	***r***
Right	Flex.	PTH	8	8.94	71.50	20.50	-.87	.38	-.22
	maxTorque(Nm)	PTN	7	6.93	48.50				
	Ext.	PTH	8	9.25	74	18	-1.16	.25	-.30
	maxTorque(Nm)	PTN	7	6.57	46				
	flex.	PTH	8	9.44	75.50	16.50	-1.34	.18	-.35
	maxTorque/weight	PTN	7	6.36	44.50				
	Ext.	PTH	8	9.81	78.50	13.50	-1.70	.09	-.44
	maxTorque/weight	PTN	7	5.93	41.50				
	Flex.	PTH	8	9.25	74	18	-1.16	.25	-.30
	peak power (W)	PTN	7	6.57	46				
	Ext.	PTH	8	9.56	76.50	15.50	-1.45	.15	-.37
	peak power (W)	PTN	7	6.21	43.50				
	Flex./ext.	PTH	8	7.75	62	26	-.23	.82	-.06
		PTN	7	8.29	58				
Left	Flex.	PTH	8	9.63	77	15	-1.51	.13	-.39
	maxTorque(Nm)	PTN	7	6.14	43				
	Ext.	PTH	8	9.69	77.50	14.50	-1.56	.12	-.40
	maxTorque(Nm)	PTN	7	6.07	42.50				
	flex.	PTH	8	9.88	79	13	-1.75	.08	-.45
	maxTorque/weight	PTN	7	5.86	41				
	Ext.	PTH	8	10.94	87.50	4.50	-2.73	**.01***	-.70
	maxTorque/weight	PTN	7	4.64	32.50				
	Flex.	PTH	8	9.75	78	14	-1.63	.10	-.42
	peak power (W)	PTN	7	6	42				
	Ext.	PTH	8	10.19	81.50	10.50	-2.03	.04	-.52
	peak power (W)	PTN	7	5.50	38.50				
	Flex./ext.	PTH	8	7.31	58.50	22.50	-.64	.52	-.17
		PTN	7	8.79	61.50				

*p < .017

As for the left leg, significant difference was detected among the groups in Ext. maxTorque/weight *H*(2) =7.80, *p* = .02 and Ext.peak power *H*(2) = 5.97, *p* = .05, (p ≤ .05), however, no significant difference was observed in Flex.maxTorque (Nm) *H*(2) = 3.82, *p* = .15; Ext.maxTorque (Nm) *H*(2) = 3.66, *p* = .16; Flex.maxTorque/weight *H*(2) = 3.99, *p* = .14; Flex.peak power *H*(2) = 3.42, *p* = .18; and Flex./ext. *H*(2) = .52, *p* = .77, (*p* > .05) (Table 4.21).

PTH group did not differ significantly from PTN group in respect to the variables of Flex.maxTorque (Nm) (*U* = 20.50, *z* = -.87, *p* = .38, *r* = -.22), Ext.maxTorque (Nm) (*U* = 18, *z* = -1.16, *p* = .25, *r* = -.30), Flex.maxTorque/weight (*U* = 16.50, *z*

$= -1.34$, $p = .18$, $r = -.35$), Ext.maxTorque/weight ($U = 13.50$, $z = -1.70$, $p = .09$, $r = -.44$), Flex.peak power ($U = 18$, $z = -1.16$, $p = .25$, $r = -.30$), Ext.peak power ($U = 15.50$, $z = -1.45$, $p = .15$, $r = -.37$) and Flex./ext. ($U = 26$, $z = -.23$, $p = .82$, $r = -.06$), $p > .017$, for the right leg (Table 4.22).

As for the left leg, Ext.maxTorque/weight value of PTH significantly greater than that of PTN ($U = 4.50$, $z = -2.73$, $p = .01$, $r = -.70$), $p < .017$; but there was no significant difference in the variables of Flex.maxTorque (Nm) ($U = 15$, $z = -1.51$, $p = .13$, $r = -.39$), Ext.maxTorque (Nm) ($U = 14.50$, $z = -1.56$, $p = .12$, $r = -.40$), Flex.maxTorque/weight ($U = 13$, $z = -1.75$, $p = .08$, $r = -.45$), Flex.peak power ($U = 14$, $z = -1.63$, $p = .10$, $r = -.42$), Ext.peak power ($U = 10.50$, $z = -2.03$, $p = .04$, $r = -.52$) and Flex./ext. ($U = 22.50$, $z = -.64$, $p = .52$, $r = -.17$), $p > .017$, between these two groups (Table 4.22).

For the right leg, PTH group did not differ significantly from Control group in regard to the values of Flex.maxTorque (Nm) ($U = 10.50$, $z = -2.27$, $p = .02$, $r = -.57$), Ext.maxTorque (Nm) ($U = 19$, $z = -1.37$, $p = .17$, $r = -.34$), Flex.maxTorque/weight ($U = 13.50$, $z = -1.96$, $p = .05$, $r = -.49$), Ext.maxTorque/weight ($U = 18.50$, $z = -1.43$, $p = .15$, $r = -.36$), Ext.peak power ($U = 15$, $z = -1.79$, $p = .07$, $r = -.45$) and Flex./ext. ($U = 28$, $z = -.42$, $p = .67$, $r = -.11$), $p > .017$; but Flex.peak power in PTH was significantly greater than that of Control group ($U = 6.50$, $z = -2.70$, $p = .01$, $r = -.68$), $p < .017$ (Table 4.23).

According to the left leg results, there was no significant difference in Flex.maxTorque (Nm) ($U = 15$, $z = -1.79$, $p = .07$, $r = -.45$), Ext.maxTorque (Nm) ($U = 16$, $z = -1.68$, $p = .09$, $r = -.42$), Flex.maxTorque/weight ($U = 17.50$, $z = -1.54$, $p = .12$, $r = -.39$), Ext.maxTorque/weight ($U = 14.50$, $z = -1.85$, $p = .07$, $r = -.46$), Flex.peak power ($U = 17.50$, $z = -1.52$, $p = .13$, $r = -.38$), Ext.peak power ($U = 12$, $z = -2.10$, $p = .04$, $r = -.53$) and Flex./ext. ($U = 26.50$, $z = -.58$, $p = .56$, $r = -.15$), $p > .017$, between PTH and Control groups (Table 4.23).

Table 4.23

Mann–Whitney Test Results between Hypoxia-Control groups at 60°/sec

	Variable	***Group***	***n***	***Mean Rank***	***Sum of Ranks***	***U***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	PTH	8	11.19	89.50	10.50	-2.27	.02	-.57
		Control	8	5.81	46.50				
	Ext. maxTorque(Nm)	PTH	8	10.13	81	19	-1.37	.17	-.34
		Control	8	6.88	55				
	Flex. maxTorque/weight	PTH	8	10.81	86.50	13.50	-1.96	.05	-.49
		Control	8	6.19	49.50				
	Ext. maxTorque/weight	PTH	8	10.19	81.50	18.50	-1.43	.15	-.36
		Control	8	6.81	54.50				
	Flex. peak power (W)	PTH	8	11.69	93.50	6.50	-2.70	**.01***	-.68
		Control	8	5.31	42.50				
	Ext. peak power (W)	PTH	8	10.63	85	15	-1.79	.07	-.45
		Control	8	6.38	51				
	Flex./ext.	PTH	8	9	72	28	-.42	.67	-.11
		Control	8	8	64				
Left	Flex. maxTorque(Nm)	PTH	8	10.63	85	15	-1.79	.07	-.45
		Control	8	6.38	51				
	Ext. maxTorque(Nm)	PTH	8	10.50	84	16	-1.68	.09	-.42
		Control	8	6.50	52				
	Flex. maxTorque/weight	PTH	8	10.31	82.50	17.50	-1.54	.12	-.39
		Control	8	6.69	53.50				
	Ext. maxTorque/weight	PTH	8	10.69	85.50	14.50	-1.85	.07	-.46
		Control	8	6.31	50.50				
	Flex. peak power (W)	PTH	8	10.31	82.50	17.50	-1.52	.13	-.38
		Control	8	6.69	53.50				
	Ext. peak power (W)	PTH	8	11	88	12	-2.10	.04	-.53
		Control	8	6	48				
	Flex./ext.	PTH	8	7.81	62.50	26.50	-.58	.56	-.15
		Control	8	9.19	73.50				

*p < .017

As for the comparisons of the differences between PTN and Control group, there were no significant differences in Flex.maxTorque (*U* = 16.50, *z* = -1.33, *p* = .18, *r* = -.34), Ext.maxTorque (*U* = 26, *z* = -.23, *p* = .82, *r* = -.06), Flex.maxTorque/weight (*U* = 27, *z* = -.12, *p* = .91, *r* = -.03), Ext.maxTorque/weight (*U* = 22.50, *z* = -.64, *p* = .52, *r* = -.17), Flex.peak power (*U* = 17.50, *z* = -1.22, *p* = .22, *r* = -.32), Ext.peak power (*U* = 25, *z* = -.35, *p* = .73, *r* = -.09) and Flex./ext. (*U* = 23, *z* = -.58, *p* = .56, *r* = -.15), *p* > .017 in right leg (Table 4.24).

There were also no significant differences in Flex.maxTorque ($U = 26$, $z = -.23$, $p = .82$, $r = -.06$), Ext.maxTorque ($U = 26$, $z = -.23$, $p = .82$, $r = -.06$), Flex.maxTorque/weight ($U = 22$, $z = -.70$, $p = .48$, $r = -.18$), Ext.maxTorque/weight ($U = 21$, $z = -.81$, $p = .42$, $r = -.21$), Flex.peak power ($U = 26$, $z = -.23$, $p = .82$, $r = -.06$), Ext.peak power ($U = 24$, $z = -.47$, $p = .64$, $r = -.12$) and Flex./ext. ($U = 26$, $z = -.23$, $p = .82$, $r = -.06$), $p > .017$ in left leg evaluations (Table 4.24).

Table 4.24
Mann–Whitney Test Results between Normoxia-Control groups at 60°/sec

	Variable	***Group***	*n*	***Mean Rank***	***Sum of Ranks***	*U*	*z*	*p*	*r*
Right	Flex. maxTorque(Nm)	PTN	7	9.64	67.50	16.50	-1.33	.18	-.34
		Control	8	6.56	52.50				
	Ext. maxTorque(Nm)	PTN	7	8.29	58	26	-.23	.82	-.06
		Control	8	7.75	62				
	Flex. maxTorque/weight	PTN	7	8.14	57	27	-.12	.91	-.03
		Control	8	7.88	63				
	Ext. maxTorque/weight	PTN	7	7.21	50.50	22.50	-.64	.52	-.17
		Control	8	8.69	69.50				
	Flex. peak power (W)	PTN	7	9.50	66.50	17.50	-1.22	.22	-.32
		Control	8	6.69	53.50				
	Ext. peak power (W)	PTN	7	8.43	59	25	-.35	.73	-.09
		Control	8	7.63	61				
	Flex./ext.	PTN	7	8.71	61	23	-.58	.56	-.15
		Control	8	7.38	59				
Left	Flex. maxTorque(Nm)	PTN	7	8.29	58	26	-.23	.82	-.06
		Control	8	7.75	62				
	Ext. maxTorque(Nm)	PTN	7	8.29	58	26	-.23	.82	-.06
		Control	8	7.75	62				
	Flex. maxTorque/weight	PTN	7	7.14	50	22	-.70	.48	-.18
		Control	8	8.75	70				
	Ext. maxTorque/weight	PTN	7	7	49	21	-.81	.42	-.21
		Control	8	8.88	71				
	Flex. peak power (W)	PTN	7	8.29	58	26	-.23	.82	-.06
		Control	8	7.75	62				
	Ext. peak power (W)	PTN	7	8.57	60	24	-.47	.64	-.12
		Control	8	7.50	60				
	Flex./ext.	PTN	7	7.71	54	26	-.23	.82	-.06
		Control	8	8.25	66				

p > .017

For the isokinetic strength test results at the speed of 60°/sec, plyometric training in normobaric hypoxia significantly increased the values of Flex.maxTorque (Nm)

($z = -1.95$, $p = .05$, $r = -.49$) and Flex.peak power ($z = -1.96$, $p = .05$, $r = -.49$), $p \leq .05$; but induced a non-significant increase in Ext.maxTorque (Nm) ($z = -.76$, $p = .45$, $r = -.19$), Flex.maxTorque/weight ($z = -1.87$, $p = .06$, $r = -.47$), Ext.maxTorque/weight ($z = -.94$, $p = .35$, $r = -.24$) Ext.peak power ($z = -.84$, $p = .40$, $r = -.21$) and Flex./ext. ($z = -1.54$, $p = .12$, $r = -.39$), $p > .05$, between pre- and post-test results, for the right leg (Table 4.25).

According to the left leg results at the speed of 60°/sec, there was a non-significant increase in Flex.maxTorque (Nm) ($z = -.85$, $p = .40$, $r = -.21$), Flex.maxTorque/weight ($z = -.42$, $p = .67$, $r = -.11$), Flex.peak power ($z = -.77$, $p = .44$, $r = -.19$), Ext.peak power ($z = -1.19$, $p = .24$, $r = -.30$) and Flex./ext. ($z = -.42$, $p = .67$, $r = -.11$), and a non-significant decrease in Ext.maxTorque (Nm) ($z = -.42$, $p = .67$, $r = -.11$) and Ext.maxTorque/weight ($z = -.73$, $p = .46$, $r = -.18$), $p > .05$, as a result of the plyometric training in normobaric hypoxia (Table 4.25).

For the isokinetic strength test results at the speed of 60°/sec, plyometric training in normoxia showed a non-significant increase in the variables of Flex.maxTorque (Nm) ($z = -1.52$, $p = .13$, $r = -.41$), Ext.maxTorque (Nm) ($z = -1.35$, $p = .18$, $r = -.36$), Flex.peak power ($z = -1.52$, $p = .13$, $r = -.41$), Ext.peak power ($z = -1.35$, $p = .18$, $r = -.36$) and Flex./ext. ($z = -1.01$, $p = .31$, $r = -.27$) and non-significant decrease in Flex.maxTorque/weight ($z = -.51$, $p = .61$, $r = -.14$) and Ext.maxTorque/weight ($z = -.34$, $p = .74$, $r = -.09$), $p > .05$, between pre- and post-test results, for the right leg (Table 4.26).

As for the left leg results at the speed of 60°/sec, there was also a non-significant increase in Flex.maxTorque (Nm) ($z = -.51$, $p = .61$, $r = -.14$), Ext.maxTorque (Nm) ($z = -.85$, $p = .40$, $r = -.23$), Flex.peak power ($z = -.34$, $p = .74$, $r = -.09$), Ext.peak power ($z = -1.44$, $p = .15$, $r = -.38$), Flex./ext. ($z = -.51$, $p = .61$, $r = -.14$), and a non-significant decrease in Flex.maxTorque/weight ($z = -1.26$, $p = .21$, $r = -.34$) and Ext.maxTorque/weight ($z = -.84$, $p = .40$, $r = -.22$), $p > .05$, between pre- and post-test results (Table 4.26).

Table 4.25

Intragroup Comparison of Isokinetic Test results at 60°/sec in PTH Group

	Variable	***Post-pretest***	*n*	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	Negative Ranks	1	2.50	2.50	-1.95	**.05***	-.49
		Positive Ranks	6	4.25	25.50			
		Ties	1	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	3	3.17	9.50	-.76	.45	-.19
		Positive Ranks	4	4.63	18.50			
		Ties	1	-	-			
	Flex. maxTorque/weight	Negative Ranks	1	3	3	-1.87	.06	-.47
		Positive Ranks	6	4.17	25			
		Ties	1	-	-			
	Ext. maxTorque/weight	Negative Ranks	3	2.83	8.50	-.94	.35	-.24
		Positive Ranks	4	4.88	19.50			
		Ties	1	-	-			
	Flex. peak power (W)	Negative Ranks	1	4	4	-1.96	**.05***	-.49
		Positive Ranks	7	4.57	32			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	4	3	12	-.84	.40	-.21
		Positive Ranks	4	6	24			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	1	7	7	-1.54	.12	-.39
		Positive Ranks	7	4.14	29			
		Ties	0	-	-			
Left	Flex. maxTorque(Nm)	Negative Ranks	2	4.50	9	-.85	.40	-.21
		Positive Ranks	5	3.80	19			
		Ties	1	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	2	4.25	8.50	-.42	.67	-.11
		Positive Ranks	4	3.13	12.50			
		Ties	2	-	-			
	Flex. maxTorque/weight	Negative Ranks	3	5	15	-.42	.67	-.11
		Positive Ranks	5	4.20	21			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	2	3.50	7	-.73	.46	-.18
		Positive Ranks	4	3.50	14			
		Ties	2	-	-			
	Flex. peak power (W)	Negative Ranks	3	4.17	12.50	-.77	.44	-.19
		Positive Ranks	5	4.70	23.50			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	1	7	7	-1.19	.24	-.30
		Positive Ranks	6	3.50	21			
		Ties	1	-	-			
	Flex./ext.	Negative Ranks	4	3.75	15	-.42	.67	-.11
		Positive Ranks	4	5.25	21			
		Ties	0	-	-			

***p** ≤.05

Table 4.26

Intragroup Comparison of Isokinetic Test results at 60°/sec in PTN Group

	Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	Negative Ranks	2	2.50	5	-1.52	.13	-.41
		Positive Ranks	5	4.60	23			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	3	2	6	-1.35	.18	-.36
		Positive Ranks	4	5.50	22			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	4	4.25	17	-.51	.61	-.14
		Positive Ranks	3	3.67	11			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	4	4	16	-.34	.74	-.09
		Positive Ranks	3	4	12			
		Ties	0	-	-			
	Flex. peak power (W)	Negative Ranks	2	2.50	5	-1.52	.13	-.41
		Positive Ranks	5	4.60	23			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	1	6	6	-1.35	.18	-.36
		Positive Ranks	6	3.67	22			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	3	2.67	8	-1.01	.31	-.27
		Positive Ranks	4	5	20			
		Ties	0	-	-			
Left	Flex. maxTorque(Nm)	Negative Ranks	2	5.50	11	-.51	.61	-.14
		Positive Ranks	5	3.40	17			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	2	4.50	9	-.85	.40	-.23
		Positive Ranks	5	3.80	19			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	4	4.13	16.50	-1.26	.21	-.34
		Positive Ranks	2	2.25	4.50			
		Ties	1	-	-			
	Ext. maxTorque/weight	Negative Ranks	4	3.63	14.50	-.84	.40	-.22
		Positive Ranks	2	3.25	6.50			
		Ties	1	-	-			
	Flex. peak power (W)	Negative Ranks	2	6	12	-.34	.74	-.09
		Positive Ranks	5	3.20	16			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	2	2.75	5.50	-1.44	.15	-.38
		Positive Ranks	5	4.50	22.50			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	2	5.50	11	-.51	.61	-.14
		Positive Ranks	5	3.40	17			
		Ties	0	-	-			

$p > .05$

Table 4.27
Intragroup Comparison of Isokinetic Test results at 60°/sec in Control Group

	Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	Negative Ranks	4	5	20	-.28	.78	-.07
		Positive Ranks	4	4	16			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	8	4.50	36	-2.53	**.01***	-.63
		Positive Ranks	0	.00	.00			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	3	5.50	16.50	-.21	.83	-.05
		Positive Ranks	5	3.90	19.50			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	5	3.10	15.50	-1.05	.29	-.26
		Positive Ranks	1	5.50	5.50			
		Ties	2	-	-			
	Flex. peak power (W)	Negative Ranks	4	4.50	18	.00	1	0
		Positive Ranks	4	4.50	18			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	5	4.90	24.50	-.91	.36	-.23
		Positive Ranks	3	3.83	11.50			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	3	4	12	-.84	.40	-.21
		Positive Ranks	5	4.80	24			
		Ties	0	-	-			
Left	Flex. maxTorque(Nm)	Negative Ranks	5	4.50	22.50	-1.44	.15	-.36
		Positive Ranks	2	2.75	5.50			
		Ties	1	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	8	4.50	36	-2.52	**.01***	-.63
		Positive Ranks	0	.00	.00			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	5	4.20	21	-1.19	.23	-.30
		Positive Ranks	2	3.50	7			
		Ties	1	-	-			
	Ext. maxTorque/weight	Negative Ranks	7	4.86	34	-2.25	**.02***	-.56
		Positive Ranks	1	2	2			
		Ties	0	-	-			
	Flex. peak power (W)	Negative Ranks	5	4.30	21.50	-1.27	.20	-.32
		Positive Ranks	2	3.25	6.50			
		Ties	1	-	-			
	Ext. peak power (W)	Negative Ranks	7	4.57	32	-1.96	**.05***	-.49
		Positive Ranks	1	4	4			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	4	2.50	10	-1.12	.26	-.28
		Positive Ranks	4	6.50	26			
		Ties	0	-	-			

*p ≤ .05

As for the control group, between pre- and post-test results, there was a significant decrease in Ext.maxTorque (z = -2.53, p = .01, r = -.63), $p < .05$ and non-significant decrease in Flex.maxTorque (z = -.28, p = .78, r = -.07), Ext.maxTorque/weight (*z* = -1.05, *p* = .29, *r* = -.26), Ext.peak power (*z* = -.91, *p* = .36, *r* = -.23) and non-significant increase in Flex.maxTorque/weight (*z* = -.21, *p* = .83, *r* = -.05), Flex.peak power (*z* = .00, *p* = .1) and Flex./ext. (*z* = -.84, *p* = .40, *r* = -.21), *p* > .05, in right leg measurements, as a results of isokinetic strength test at the speed of 60°/sec (Table 4.27).

According to the left leg, there was a significant decrease in Ext.maxTorque (*z* = -2.52, *p* = .01, *r* = -.63), Ext.maxTorque/weight (*z* = -2.25, *p* = .02, *r* = -.56) and Ext.peak power (*z* = -1.96, *p* = .05, *r* = -.49), $p \leq .05$, and a non-significant decrease in Flex.maxTorque (*z* = -1.44, *p* = .15, *r* = -.36), Flex.maxTorque/weight (*z* = -1.19, *p* = .23, *r* = -.30), Flex.peak power (*z* = -1.27, *p* = .20, *r* = -.32) and a non-significant increase in Flex./ext. (*z* = -1.12, *p* = .26, *r* = -.28), *p* > .05, between pre- and post-test results (Table 4.27).

Intragroup mean, standard deviation and percentage changes of isokinetic strength test variables at the speed of 180°/sec for the right and left leg evaluations were presented in Table 4.28.

Flex. maxTorque demonstrated 8.70% increase in PTH group (*M* = 110.75, *SD* = 18.87 to *M* = 120.38, *SD* = 22.74), 9.04% rise in PTN group (*M* = 99.57, *SD* = 17.04 to *M* = 108.57, *SD* = 20.33) and 19.73% decrease in Control group (*M* = 119.13, *SD* = 30.52 to *M* = 95.63, *SD* = 11.24).

In Ext. maxTorque, a 1.76% increment in PTH group (*M* = 156.13, *SD* = 39.83 to *M* = 158.88, *SD* = 27.41), a 2.48% increase in PTN group (*M* = 143.86, *SD* = 20 to *M* = 147.43, *SD* = 23.99) and a 16.61% decrease in Control group (*M* = 163.25, *SD* = 23.10 to *M* = 136.13, *SD* = 18.99) were observed.

As for the Flex. maxTorque/weight value, a 9.55% increase in PTH group (*M* = 1.57, *SD* = .29 to *M* = 1.72, *SD* = .24), a 2.92% reduction in PTN group (*M* = 1.37, *SD* = .21 to *M* = 1.33, *SD* = .58) and a 11.32% decrease in Control group (*M* = 1.59, *SD* = .43 to *M* = 1.41, *SD* = .20) were detected. Ext. maxTorque/weight showed 2.26% rise in PTH group (*M* = 2.21, *SD* = .33 to *M* = 2.26, *SD* = .17), 10%

decrease in PTN group (*M* = 2.00, *SD* = .12 to *M* = 1.80, *SD* = .73) and 8.22% reduction in Control group (*M* = 2.19, *SD* = .19 to *M* = 2.01, *SD* = .22).

A 12.30% rise in PTH (*M* = 182, *SD* = 39.05 to *M* = 204.38, *SD* = 44.87), 5.57% increase in PTN (*M* = 159.14, *SD* = 32.97 to *M* = 168, *SD* = 31.62) and 23.11% decrease in Control group (*M* = 198.50, *SD* = 54.15 to *M* = 152.63, *SD* = 28.15) were found in Flex. peak power.

In Ext. peak power value, there was a 0.86% increase in PTH (*M* = 248.75, *SD* = 55.68 to *M* = 250.88, *SD* = 43.57), a 0.70% increment in PTN (*M* = 224.57, *SD* = 24.50 to *M* = 226.14, *SD* = 36.77) and a 21.37% decline in Control group (*M* = 263.25, *SD* = 42.35 to *M* = 207, *SD* = 25.91). The value of Flex./Ext. showed a 4.11% increase in PTH (*M* = .73, *SD* = .12 to *M* = .76, *SD* = .07), a 7.25% rise in PTN (*M* = .69, *SD* = .09 to *M* = .74, *SD* = .10) and 2.74% decrease in Control group (*M* = .73, *SD* = .13 to *M* = .71, *SD* = .12). The above results belong to the right leg results (Table 4.28).

As for the left leg evaluations, a 3.25% increase in PTH (*M* = 119.13, *SD* = 38.67 to *M* = 123, *SD* = 23.02), a 1.48% rise in PTN (*M* = 106.29, *SD* = 16.87 to *M* = 107.86, *SD* = 22.71) and a 19.64% decline in Control group (*M* = 122.88, *SD* = 23.51 to *M* = 98.75, *SD* = 11.47) were observed in Flex. maxTorque. The value of Ext. maxTorque demonstrated a 0.93% increase in PTH (*M* = 160.63, *SD* = 43.28 to *M* = 162.13, *SD* = 38.74), a 5.98% decrease in PTN (*M* = 145.71, *SD* = 26.83 to *M* = 137, *SD* = 17.74) and a 16.03% reduction in Control group (*M* = 159.88, *SD* = 23.93 to *M* = 134.25, *SD* = 26.44).

In Flex. maxTorque/weight , while there was a 5.36% increase in PTH (*M* = 1.68, *SD* = .45 to *M* = 1.77, *SD* = .33), there was a 7.53% decrease in PTN (*M* = 1.46, *SD* = .15 to *M* = 1.35, *SD* = .66) and a 9.76% decline in Control group (*M* = 1.64, *SD* = .31 to *M* = 1.48, *SD* = .21). Ext. maxTorque/weight presented a 2.67% increase in PTH (*M* = 2.25, *SD* = .39 to *M* = 2.31, *SD* = .37), a 16.5% decrease in PTN (*M* = 2.00, *SD* = .16 to *M* = 1.67, *SD* = .67) and a 7.48% reduction in Control group (*M* = 2.14, *SD* = .27 to *M* = 1.98, *SD* = .34).

In Flex. peak power, while a 9.33% increase in PTH (*M* = 179.50, *SD* = 63.01 to *M* = 196.25, *SD* = 42.33) was found, a 11.61% decrease in PTN (*M* = 176, *SD* = 36.93 to *M* = 155.57, *SD* = 16.04) and a 21.26% decrease were observed in Control group (*M* = 198.75, *SD* = 43.23 to *M* = 156.50, *SD* = 15.86). As for the Ext.peak power, there was a 1.78% increment in PTH (*M* = 246.25, *SD* = 57.95 to *M* = 250.63, *SD* = 49.41), 7.04% decline in PTN (*M* = 229.14, *SD* = 44.04 to *M* = 213, *SD* = 21.24) and 23.93% decrease in Control group (*M* = 251.75, *SD* = 36.46 to *M* = 191.50, *SD* = 35.65). Flex./Ext. value showed a 4% increase in PTH (*M* = .75, *SD* = .15 to *M* = .78, *SD* = .13), a 8.11% increase in PTN (*M* = .74, *SD* = .10 to *M* = .80, *SD* = .21) and a 1.30% decrease in Control group (*M* = .77, *SD* = .11 to *M* = .76, *SD* = .18) (Table 4.28).

With respect to the pre-test results of Kruskal Wallis Test for the isokinetic strength at the speed of 180°/sec, no significant difference was found among the groups in Flex.maxTorque *H*(2) = 2.10, *p* = .35; Ext.maxTorque *H*(2) = 1.27, *p* = .53; Flex.maxTorque/weight *H*(2) = 2.09, *p* = .35; Ext. maxTorque/weight *H*(2) = 4.85, *p* = .09; Flex.peak power *H*(2) = 4.16, *p* = .13; Ext.peak power *H*(2) = 2.93, *p* = .23; and Flex./Ext. *H*(2) = .23, *p* = .89, for the right leg (Table 4.29). As for the left leg, there was no significant difference among the groups in Flex.maxTorque *H*(2) = 1.61, *p* = .45; Ext.maxTorque *H*(2) = .82, *p* = .66; Flex.maxTorque/weight *H*(2) = 2.02, *p* = .37; Ext. maxTorque/weight *H*(2) = 2.52, *p* = .28; Flex.peak power *H*(2) = .76, *p* = .68; Ext.peak power *H*(2) = .70, *p* = .70; and Flex./Ext. *H*(2) = .29, *p* = .87; *p*> .05 (Table 4.29).

In accordance with the post-test results of isokinetic strength test at the speed of 180°/sec, while there was a significant difference was observed among the groups in Flex.maxTorque/weight *H*(2) = 6.47, *p* = .04, (*p* < .05), no significant difference was found in the variables of Flex.maxTorque *H*(2) = 5.41, *p* = .07; Ext.maxTorque *H*(2) = 2.26, *p* = .32; Ext. maxTorque/weight *H*(2) = 3.64, *p* = .16; Flex.peak power *H*(2) = 5.65, *p* = .06; Ext.peak power *H*(2) = 4.19, *p* = .12; and Flex./Ext. *H*(2) = .95, *p* = .62; *p* > .05, for the right leg (Table 4.30).

Table 4.28

Intragroup Mean, Standard Deviation and Percentage Changes of Isokinetic Test Variables at 180°/sec

	Variable	***Group***	***n***	***Pre-test M±SD***	***Post-test M±SD***	***Change (%)***
Right	Flex. maxTorque(Nm)	PTH	8	110.75±18.87	120.38±22.74	8.70
		PTN	7	99.57±17.04	108.57±20.33	9.04
		Control	8	119.13±30.52	95.63±11.24	19.73
	Ext. maxTorque(Nm)	PTH	8	156.13±39.83	158.88±27.41	1.76
		PTN	7	143.86±20	147.43±23.99	2.48
		Control	8	163.25±23.10	136.13±18.99	16.61
	Flex. maxTorque/weight	PTH	8	1.57±.29	1.72±.24	9.55
		PTN	7	1.37±.21	1.33±.58	2.92
		Control	8	1.59±.43	1.41±.20	11.32
	Ext. maxTorque/weight	PTH	8	2.21±.33	2.26±.17	2.26
		PTN	7	2.00±.12	1.80±.73	10
		Control	8	2.19±.19	2.01±.22	8.22
	Flex. peak power (W)	PTH	8	182±39.05	204.38±44.87	12.30
		PTN	7	159.14±32.97	168±31.62	5.57
		Control	8	198.50±54.15	152.63±28.15	23.11
	Ext. peak power (W)	PTH	8	248.75±55.68	250.88±43.57	0.86
		PTN	7	224.57±24.50	226.14±36.77	0.70
		Control	8	263.25±42.35	207±25.91	21.37
	Flex./ext.	PTH	8	.73±.12	.76±.07	4.11
		PTN	7	.69±.09	.74±.10	7.25
		Control	8	.73±.13	.71±.12	2.74
Left	Flex. maxTorque(Nm)	PTH	8	119.13±38.67	123±23.02	3.25
		PTN	7	106.29±16.87	107.86±22.71	1.48
		Control	8	122.88±23.51	98.75±11.47	19.64
	Ext. maxTorque(Nm)	PTH	8	160.63±43.28	162.13±38.74	0.93
		PTN	7	145.71±26.83	137±17.74	5.98
		Control	8	159.88±23.93	134.25±26.44	16.03
	Flex. maxTorque/weight	PTH	8	1.68±.45	1.77±.33	5.36
		PTN	7	1.46±.15	1.35±.66	7.53
		Control	8	1.64±.31	1.48±.21	9.76
	Ext. maxTorque/weight	PTH	8	2.25±.39	2.31±.37	2.67
		PTN	7	2.00±.16	1.67±.67	16.5
		Control	8	2.14±.27	1.98±.34	7.48
	Flex. peak power (W)	PTH	8	179.50±63.01	196.25±42.33	9.33
		PTN	7	176±36.93	155.57±16.04	11.61
		Control	8	198.75±43.23	156.50±15.86	21.26
	Ext. peak power (W)	PTH	8	246.25±57.95	250.63±49.41	1.78
		PTN	7	229.14±44.04	213±21.24	7.04
		Control	8	251.75±36.46	191.50±35.65	23.93
	Flex./ext.	PTH	8	.75±.15	.78±.13	4
		PTN	7	.74±.10	.80±.21	8.11
		Control	8	.77±.11	.76±.18	1.30

Flex. : Flexion, **Ext.** : Extension

Table 4.29

Intergroup Comparisons of Isokinetic Test results at 180°/sec in Pre-test

	Variable	***Group***	***n***	***Mean Rank***	***sd***	***X^2***	***p***
Right	Flex. maxTorque(Nm)	PTH	8	13.06	2	2.10	.35
		PTN	7	8.93			
		Control	8	13.63			
	Ext. maxTorque(Nm)	PTH	8	12.06	2	1.27	.53
		PTN	7	9.86			
		Control	8	13.81			
	Flex. maxTorque/weight	PTH	8	13.81	2	2.09	.35
		PTN	7	9			
		Control	8	12.81			
	Ext. maxTorque/weight	PTH	8	12.94	2	4.85	.09
		PTN	7	7.57			
		Control	8	14.94			
	Flex. peak power (W)	PTH	8	12.38	2	4.16	.13
		PTN	7	8			
		Control	8	15.13			
	Ext. peak power (W)	PTH	8	12.31	2	2.93	.23
		PTN	7	8.64			
		Control	8	14.63			
	Flex./ext.	PTH	8	12.25	2	.23	.89
		PTN	7	11			
		Control	8	12.63			
Left	Flex. maxTorque(Nm)	PTH	8	11.63	2	1.61	.45
		PTN	7	9.86			
		Control	8	14.25			
	Ext. maxTorque(Nm)	PTH	8	13.25	2	.82	.66
		PTN	7	10.14			
		Control	8	12.38			
	Flex. maxTorque/weight	PTH	8	13.06	2	2.02	.37
		PTN	7	9			
		Control	8	13.56			
	Ext. maxTorque/weight	PTH	8	14	2	2.52	.28
		PTN	7	8.71			
		Control	8	12.88			
	Flex. peak power (W)	PTH	8	11.06	2	.76	.68
		PTN	7	11.14			
		Control	8	13.69			
	Ext. peak power (W)	PTH	8	12.88	2	.70	.70
		PTN	7	10.21			
		Control	8	12.69			
	Flex./ext.	PTH	8	11.69	2	.29	.87
		PTN	7	11.21			
		Control	8	13			

$p > .05$

Table 4.30

Intergroup Comparisons of Isokinetic Test results at 180°/sec in Post-test

	Variable	***Group***	***n***	***Mean Rank***	***sd***	***X^2***	***p***
Right	Flex. maxTorque(Nm)	PTH	8	15.88	2	5.41	.07
		PTN	7	12.14			
		Control	8	8			
	Ext. maxTorque(Nm)	PTH	8	14.38	2	2.26	.32
		PTN	7	12.36			
		Control	8	9.31			
	Flex. maxTorque/weight	PTH	8	16.63	2	6.47	**.04***
		PTN	7	11.07			
		Control	8	8.19			
	Ext. maxTorque/weight	PTH	8	15.63	2	3.64	.16
		PTN	7	10.50			
		Control	8	9.69			
	Flex. peak power (W)	PTH	8	16.25	2	5.65	.06
		PTN	7	11.43			
		Control	8	8.25			
	Ext. peak power (W)	PTH	8	15.44	2	4.19	.12
		PTN	7	12.07			
		Control	8	8.50			
	Flex./ext.	PTH	8	13.88	2	.95	.62
		PTN	7	11.21			
		Control	8	10.81			
Left	Flex. maxTorque(Nm)	PTH	8	16.38	2	5.74	.06
		PTN	7	11.14			
		Control	8	8.38			
	Ext. maxTorque(Nm)	PTH	8	15.25	2	2.85	.24
		PTN	7	10.57			
		Control	8	10			
	Flex. maxTorque/weight	PTH	8	15.56	2	3.53	.17
		PTN	7	10.71			
		Control	8	9.56			
	Ext. maxTorque/weight	PTH	8	15.88	2	4.30	.12
		PTN	7	9			
		Control	8	10.75			
	Flex. peak power (W)	PTH	8	17.88	2	9.27	**.01***
		PTN	7	8.57			
		Control	8	9.13			
	Ext. peak power (W)	PTH	8	16.31	2	6.04	**.05***
		PTN	7	11.64			
		Control	8	8			
	Flex./ext.	PTH	8	12.50	2	.21	.90
		PTN	7	12.43			
		Control	8	11.13			

*$p \leq .05$

In terms of the left leg measurements, while there was a significant difference among the groups in the variables of Flex.peak power $H(2) = 9.27$, $p = .01$ and Ext.peak power $H(2) = 6.04$, $p = .05$, ($p \leq .05$), there was no significant difference in Flex.maxTorque $H(2) = 5.74$, $p = .06$; Ext.maxTorque $H(2) = 2.85$, $p = .24$; Flex.maxTorque/weight $H(2) = 3.53$, $p = .17$; Ext. maxTorque/weight $H(2) = 4.30$, $p = .12$; and Flex./Ext. $H(2) = .21$, $p = .90$; $p > .05$ among the groups (Table 4.30).

As for the comparisons of the differences between PTH and PTN groups, there were no significant differences in Flex.maxTorque ($U = 19$, $z = -1.04$, $p = .30$, $r = -.27$), Ext.maxTorque ($U = 22$, $z = -.69$, $p = .49$, $r = -.18$), Flex.maxTorque/weight ($U = 16.50$, $z = -1.35$, $p = .18$, $r = -.35$), Ext.maxTorque/weight ($U = 17.50$, $z = -1.23$, $p = .22$, $r = -.32$), Flex.peak power ($U = 15$, $z = -1.51$, $p = .13$, $r = -.39$), Ext.peak power ($U = 19$, $z = -1.04$, $p = .30$, $r = -.27$) and Flex./Ext. ($U = 20$, $z = -.93$, $p = .36$, $r = -.24$), $p > .017$ in right leg evaluations (Table 4.31).

However, for the left leg, Flex.peak power of PTH was significantly greater than that of PTN ($U = 5.50$, $z = -2.61$, $p = .01$, $r = -.67$), $p < .017$; but there was no significant difference in the variables of Flex.maxTorque ($U = 16$, $z = -1.39$, $p = .17$, $r = -.36$), Ext.maxTorque ($U = 16$, $z = -1.39$, $p = .17$, $r = -.36$), Flex.maxTorque/weight ($U = 16.50$, $z = -1.34$, $p = .18$, $r = -.35$), Ext.maxTorque/weight ($U = 12.50$, $z = -1.80$, $p = .07$, $r = -.46$), Ext.peak power ($U = 15.50$, $z = -1.45$, $p = .15$, $r = -.37$) and Flex./Ext. ($U = 27$, $z = -.12$, $p = .91$, $r = -.03$), $p > .017$, between these two groups (Table 4.31).

For the right leg, PTH group did not differ significantly from Control group in regard to the values of Flex.maxTorque ($U = 10$, $z = -2.32$, $p = .02$, $r = -.58$), Ext.maxTorque ($U = 19$, $z = -1.37$, $p = .17$, $r = -.38$), Ext.maxTorque/weight ($U = 13.50$, $z = -1.98$, $p = .05$, $r = -.50$), Flex.peak power ($U = 11$, $z = -2.21$, $p = .03$, $r = -.55$), Ext.peak power ($U = 13.50$, $z = -1.94$, $p = .05$, $r = -.49$) and Flex./Ext. ($U = 25$, $z = -.74$, $p = .46$, $r = -.19$), $p > .017$; but Flex.maxTorque/weight in PTH was significantly greater than that of Control group ($U = 6.50$, $z = -2.71$, $p = .01$, $r = -.68$), $p < .017$ (Table 4.32).

Table 4.31

Mann–Whitney Test Results between Hypoxia-Normoxia Groups at 180°/sec

	Variable	***Group***	***n***	***Mean Rank***	***Sum of Ranks***	***U***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	PTH	8	9.13	73	19	-1.04	.30	-.27
		PTN	7	6.71	47				
	Ext. maxTorque(Nm)	PTH	8	8.75	70	22	-.69	.49	-.18
		PTN	7	7.14	50				
	Flex. maxTorque/weight	PTH	8	9.44	75.50	16.50	-1.35	.18	-.35
		PTN	7	6.36	44.50				
	Ext. maxTorque/weight	PTH	8	9.31	74.50	17.50	-1.23	.22	-.32
		PTN	7	6.50	45.50				
	Flex. peak power (W)	PTH	8	9.63	77	15	-1.51	.13	-.39
		PTN	7	6.14	43				
	Ext. peak power (W)	PTH	8	9.13	73	19	-1.04	.30	-.27
		PTN	7	6.71	47				
	Flex./ext.	PTH	8	9	72	20	-.93	.36	-.24
		PTN	7	6.86	48				
Left	Flex. maxTorque(Nm)	PTH	8	9.50	76	16	-1.39	.17	-.36
		PTN	7	6.29	44				
	Ext. maxTorque(Nm)	PTH	8	9.50	76	16	-1.39	.17	-.36
		PTN	7	6.29	44				
	Flex. maxTorque/weight	PTH	8	9.44	75.50	16.50	-1.34	.18	-.35
		PTN	7	6.36	44.50				
	Ext. maxTorque/weight	PTH	8	9.94	79.50	12.50	-1.80	.07	-.46
		PTN	7	5.79	40.50				
	Flex. peak power (W)	PTH	8	10.81	86.50	5.50	-2.61	**.01***	-.67
		PTN	7	4.79	33.50				
	Ext. peak power (W)	PTH	8	9.56	76.50	15.50	-1.45	.15	-.37
		PTN	7	6.21	43.50				
	Flex./ext.	PTH	8	7.88	63	27	-.12	.91	-.03
		PTN	7	8.14	57				

*p < .017

In terms of the left leg results, there was no significant difference in Flex.maxTorque (U = 9, z = -2.42, p = .02, r = -.61), Ext.maxTorque (U = 18, z = -1.47, p = .14, r = -.37), Flex.maxTorque/weight (U = 15, z = -1.80, p = .07, r = -.45), Ext.maxTorque/weight (U = 16.50, z = -1.64, p = .10, r = -.41), Ext.peak power (U = 10, z = -2.31, p = .02, r = -.58) and Flex./Ext. (U = 27, z = -.53, p = .60, r = -.13), p > .017, between PTH and Control groups; but Flex.peak power value of PTH was significantly greater than Flex. peak power value of Control group (U = 7.50, z = -2.58, p = .01, r = -.65), p < .017 (Table 4.32).

Table 4.32

Mann–Whitney Test Results between Hypoxia-Control Groups at 180°/sec

	Variable	***Group***	***n***	***Mean Rank***	***Sum of Ranks***	***U***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	PTH	8	11.25	90	10	-2.32	.02	-.58
		Control	8	5.75	46				
	Ext. maxTorque(Nm)	PTH	8	10.13	81	19	-1.37	.17	-.34
		Control	8	6.88	55				
	Flex. maxTorque/weight	PTH	8	11.69	93.50	6.50	-2.71	**.01***	-.68
		Control	8	5.31	42.50				
	Ext. maxTorque/weight	PTH	8	10.81	86.50	13.50	-1.98	.05	-.50
		Control	8	6.19	49.50				
	Flex. peak power (W)	PTH	8	11.13	89	11	-2.21	.03	-.55
		Control	8	5.88	47				
	Ext. peak power (W)	PTH	8	10.81	86.50	13.50	-1.94	.05	-.49
		Control	8	6.19	49.50				
	Flex./ext.	PTH	8	9.38	75	25	-.74	.46	-.19
		Control	8	7.63	61				
Left	Flex. maxTorque(Nm)	PTH	8	11.38	91	9	-2.42	.02	-.61
		Control	8	5.63	45				
	Ext. maxTorque(Nm)	PTH	8	10.25	82	18	-1.47	.14	-.37
		Control	8	6.75	54				
	Flex. maxTorque/weight	PTH	8	10.63	85	15	-1.80	.07	-.45
		Control	8	6.38	51				
	Ext. maxTorque/weight	PTH	8	10.44	83.50	16.50	-1.64	.10	-.41
		Control	8	6.56	52.50				
	Flex. peak power (W)	PTH	8	11.56	92.50	7.50	-2.58	**.01***	-.65
		Control	8	5.44	43.50				
	Ext. peak power (W)	PTH	8	11.25	90	10	-2.31	.02	-.58
		Control	8	5.75	46				
	Flex./ext.	PTH	8	9.13	73	27	-.53	.60	-.13
		Control	8	7.88	63				

$^{*}p < .017$

As for the comparisons of the differences between PTN and Control group, there were no significant differences in Flex. maxTorque (U =18, z = -1.16, p = .25, r = -.30), Ext. maxTorque (U = 19.50, z = -.99, p = .32, r = -.26), Flex. maxTorque/weight (U = 23, z = -.59, p = .56, r = -.15), Ext. maxTorque/weight (U =28, z = .00, p = 1.00), Flex. peak power (U = 19, z = -1.04, p = .30, r = -.27), Ext. peak power (U = 18.50, z = -1.10, p = .27, r = -.28) and Flex./Ext. (U = 25.50, z = -.29, p = .77, r = -.07), p > .017 in right leg (Table 4.33).

And also, there were no significant differences in the variables of Flex. maxTorque (U = 22, z = -.70, p = .49, r = -.18), Ext. maxTorque (U = 26, z = -.23,

$p = .82$, $r = -.06$), Flex. maxTorque/weight ($U = 25.50$, $z = -.29$, $p = .77$, $r = -.07$), Ext. maxTorque/weight ($U = 22.50$, $z = -.64$, $p = .52$, $r = -.17$), Flex.peak power ($U = 26.50$, $z = -.17$, $p = .86$, $r = -.04$), Ext. peak power ($U = 18$, $z = -1.16$, $p = .25$, $r = -.30$) and Flex./Ext. ($U = 26$, $z = -.23$, $p = .82$, $r = -.06$), $p > .017$ in left leg evaluations (Table 4.33).

Table 4.33
Mann–Whitney Test Results between Normoxia-Control Groups at 180°/sec

	Variable	**Group**	n	**Mean Rank**	**Sum of Ranks**	U	z	p	r
Right	Flex. maxTorque(Nm)	PTN	7	9.43	66	18	-1.16	.25	-.30
		Control	8	6.75	54				
	Ext. maxTorque(Nm)	PTN	7	9.21	64.50	19.50	-.99	.32	-.26
		Control	8	6.94	55.50				
	Flex. maxTorque/weight	PTN	7	8.71	61	23	-.59	.56	-.15
		Control	8	7.38	59				
	Ext. maxTorque/weight	PTN	7	8	56	28	.00	1.00	0
		Control	8	8	64				
	Flex. peak power (W)	PTN	7	9.29	65	19	-1.04	.30	-.27
		Control	8	6.88	55				
	Ext. peak power (W)	PTN	7	9.36	65.50	18.50	-1.10	.27	-.28
		Control	8	6.81	54.50				
	Flex./ext.	PTN	7	8.36	58.50	25.50	-.29	.77	-.07
		Control	8	7.69	61.50				
Left	Flex. maxTorque(Nm)	PTN	7	8.86	62	22	-.70	.49	-.18
		Control	8	7.25	58				
	Ext. maxTorque(Nm)	PTN	7	8.29	58	26	-.23	.82	-.06
		Control	8	7.75	62				
	Flex. maxTorque/weight	PTN	7	8.36	58.50	25.50	-.29	.77	-.07
		Control	8	7.69	61.50				
	Ext. maxTorque/weight	PTN	7	7.21	50.50	22.50	-.64	.52	-.17
		Control	8	8.69	69.50				
	Flex. peak power (W)	PTN	7	7.79	54.50	26.50	-.17	.86	-.04
		Control	8	8.19	65.50				
	Ext. peak power (W)	PTN	7	9.43	66	18	-1.16	.25	-.30
		Control	8	6.75	54				
	Flex./ext.	PTN	7	8.29	58	26	-.23	.82	-.06
		Control	8	7.75	62				

$^*p < .017$

For the isokinetic strength test results at the speed of 180°/sec, plyometric training in normobaric hypoxia (PTH) significantly increased Flex.peak power ($z = -2.10$, $p = .04$, $r = -.53$), $p < .05$ in the right leg measurement, but made a non-significant increase in the values of Flex. maxTorque ($z = -.35$, $p = .73$, $r = -.09$), Ext.

maxTorque (*z* = -.14, *p* = .89, *r* = -.04), Flex. maxTorque/weight (*z* = -1.41, *p* = .16, *r* = -.35), Ext. maxTorque/weight (*z* = -.52, *p* = .61, *r* = -.13), Ext. peak power (*z* = .00, *p* = 1.00), Flex./Ext. (*z* = -.98, *p* = .33, *r* = -.25) in the right leg. (Table 4.34).

In addition, PTH induced a non-significant increase in Flex. maxTorque (*z* = -.14, *p* = .89, *r* = -.04), Ext. maxTorque (*z* = -.09, *p* = .93, *r* = -.02), Flex. maxTorque/weight (*z* = -.52, *p* = .60, *r* = -.13), Ext. maxTorque/weight (*z* = -1.76, *p* = .08, *r* = -.44), Flex. peak power (*z* = -.91, *p* = .36, *r* = -.23), Ext. peak power (*z* = -.51, *p* = .61, *r* = -.13) and Flex./Ext. (*z* = -.14, *p* = .89, *r* = -.04), *p* > .05, in the left leg measurements, between pre- and post-test results (Table 4.34).

For the isokinetic strength test results at the speed of 180°/sec, PTN group represented a non-significant increase in the variables of Flex. maxTorque (*z* = -.51, *p* = .61, *r* = -.14), Ext. maxTorque (*z* = -.51, *p* = .61, *r* = -.14), Flex. peak power (*z* = -.68, *p* = .50, *r* = -.18), Ext. peak power (*z* = .00, *p* = 1.00) and Flex./Ext. (*z* = -.68, *p* = .50, *r* = -.18) and a non-significant decrease in Flex. maxTorque/weight (*z* = -.17, *p* = .87, *r* = -.05) and Ext. maxTorque/weight (*z* = -.31, *p* = .75, *r* = -.08), *p* > .05, between pre- and post-test results, for the right leg (Table 4.35).

As for the left leg, there was also a non-significant increase in Flex. maxTorque (*z* = -.17, *p* = .87, *r* = -.05) and Flex./Ext. (*z* = -.68, *p* = .50, *r* = -.18); and a non-significant decrease in Ext. maxTorque (*z* = -.85, *p* = .40, *r* = -.23), Flex. maxTorque/weight (*z* = -.09, *p* = .93, *r* = -.02), Ext. maxTorque/weight (*z* = -.52, *p* = .60, *r* = -.14), Flex. peak power (*z* = -1.35, *p* = .18, *r* = -.36) and Ext. peak power (*z* = -.68, *p* = .50, *r* = -.18), *p* > .05, between pre- and post-test results (Table 4.35).

Table 4.34

Intragroup Comparison of Isokinetic Test results at 180°/sec in PTH Group

	Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	Negative Ranks	4	3.88	15.50	-.35	.73	-.09
		Positive Ranks	4	5.13	20.50			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	4	4.75	19	-.14	.89	-.04
		Positive Ranks	4	4.25	17			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	3	2.67	8	-1.41	.16	-.35
		Positive Ranks	5	5.60	28			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	2	5.50	11	-.52	.61	-.13
		Positive Ranks	5	3.40	17			
		Ties	1	-	-			
	Flex. peak power (W)	Negative Ranks	1	3	3	-2.10	**.04***	-.53
		Positive Ranks	7	4.71	33			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	4	4.50	18	.00	1.00	0
		Positive Ranks	4	4.50	18			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	4	2.75	11	-.98	.33	-.25
		Positive Ranks	4	6.25	25			
		Ties	0	-	-			
Left	Flex. maxTorque(Nm)	Negative Ranks	3	5.67	17	-.14	.89	-.04
		Positive Ranks	5	3.80	19			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	3	4.50	13.50	-.09	.93	-.02
		Positive Ranks	4	3.63	14.50			
		Ties	1	-	-			
	Flex. maxTorque/weight	Negative Ranks	2	4	8	-.52	.60	-.13
		Positive Ranks	4	3.25	13			
		Ties	2	-	-			
	Ext. maxTorque/weight	Negative Ranks	1	1	1	-1.76	.08	-.44
		Positive Ranks	4	3.50	14			
		Ties	3	-	-			
	Flex. peak power (W)	Negative Ranks	3	3.83	11.50	-.91	.36	-.23
		Positive Ranks	5	4.90	24.50			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	2	5.50	11	-.51	.61	-.13
		Positive Ranks	5	3.40	17			
		Ties	1	-	-			
	Flex./ext.	Negative Ranks	4	4.75	19	-.14	.89	-.04
		Positive Ranks	4	4.25	17			
		Ties	0	-	-			

*p <.05

For control group, between pre- and post-test results, there was a significant decrease in Flex. maxTorque (*z* = -1.96, *p* = .05, *r* = -.49), Ext. maxTorque (*z* = -2.10, *p* = .04, *r* = -.53), Flex. peak power (*z* = -2.10, *p* = .04, *r* = -.53) and Ext. peak power (*z* = -2.31, *p* = .02, *r* = -.58), *p* ≤ .05; and non-significant decrease in

Flex.maxTorque/weight ($z = -1.13$, $p = .26$, $r = -.28$), Ext.maxTorque/weight ($z = -1.83$, $p = .07$, $r = -.46$), and Flex./Ext. ($z = -.28$, $p = .78$, $r = -.07$), $p > .05$, in right leg measurements as a results of isokinetic strength test at 180°/sec (Table 4.36).

Table 4.35

Intragroup Comparison of Isokinetic Test results at 180°/sec in PTN Group

	Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	Negative Ranks	4	2.75	11	-.51	.61	-.14
		Positive Ranks	3	5.67	17			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	4	2.75	11	-.51	.61	-.14
		Positive Ranks	3	5.67	17			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	2	6.50	13	-.17	.87	-.05
		Positive Ranks	5	3	15			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	3	4	12	-.31	.75	-.08
		Positive Ranks	3	3	9			
		Ties	1	-	-			
	Flex. peak power (W)	Negative Ranks	2	5	10	-.68	.50	-.18
		Positive Ranks	5	3.60	18			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	4	3.50	14	.00	1.00	0
		Positive Ranks	3	4.67	14			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	3	3.33	10	-.68	.50	-.18
		Positive Ranks	4	4.50	18			
		Ties	0	-	-			
Left	Flex. maxTorque(Nm)	Negative Ranks	4	3.25	13	-.17	.87	-.05
		Positive Ranks	3	5	15			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	4	4.75	19	-.85	.40	-.23
		Positive Ranks	3	3	9			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	3	4.83	14.50	-.09	.93	-.02
		Positive Ranks	4	3.38	13.50			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	3	4.33	13	-.52	.60	-.14
		Positive Ranks	3	2.67	8			
		Ties	1	-	-			
	Flex. peak power (W)	Negative Ranks	4	5.50	22	-1.35	.18	-.36
		Positive Ranks	3	2	6			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	3	6	18	-.68	.50	-.18
		Positive Ranks	4	2.50	10			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	4	2.50	10	-.68	.50	-.18
		Positive Ranks	3	6	18			
		Ties	0	-	-			

$p > .05$

Table 4.36

Intragroup Comparison of Isokinetic Test results at 180°/sec in Control Group

	Variable	***Post-pretest***	***n***	***Mean Rank***	***Sum of Ranks***	***z***	***p***	***r***
Right	Flex. maxTorque(Nm)	Negative Ranks	6	5.33	32	-1.96	**.05***	-.49
		Positive Ranks	2	2	4			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	7	4.71	33	-2.10	**.04***	-53
		Positive Ranks	1	3	3			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	5	5.20	26	-1.13	.26	-.28
		Positive Ranks	3	3.33	10			
		Ties	0	-	-			
	Ext. maxTorque/weight	Negative Ranks	6	5.17	31	-1.83	.07	-.46
		Positive Ranks	2	2.50	5			
		Ties	0	-	-			
	Flex. peak power (W)	Negative Ranks	6	5.50	33	-2.10	**.04***	-.53
		Positive Ranks	2	1.50	3			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	7	4.93	34.50	-2.31	**.02***	-.58
		Positive Ranks	1	1.50	1.50			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	4	5	20	-.28	.78	-.07
		Positive Ranks	4	4	16			
		Ties	0	-	-			
Left	Flex. maxTorque(Nm)	Negative Ranks	7	5	35	-2.38	**.02***	-.60
		Positive Ranks	1	1	1			
		Ties	0	-	-			
	Ext. maxTorque(Nm)	Negative Ranks	6	5.08	30.50	-1.75	.08	-.44
		Positive Ranks	2	2.75	5.50			
		Ties	0	-	-			
	Flex. maxTorque/weight	Negative Ranks	5	4.40	22	-1.36	.17	-.34
		Positive Ranks	2	3	6			
		Ties	1	-	-			
	Ext. maxTorque/weight	Negative Ranks	6	4.17	25	-1.00	.32	-.25
		Positive Ranks	2	5.50	11			
		Ties	0	-	-			
	Flex. peak power (W)	Negative Ranks	7	5	35	-2.38	**.02***	-.60
		Positive Ranks	1	1	1			
		Ties	0	-	-			
	Ext. peak power (W)	Negative Ranks	7	4.86	34	-2.24	**.03***	-.56
		Positive Ranks	1	2	2			
		Ties	0	-	-			
	Flex./ext.	Negative Ranks	4	4.75	19	-.14	.89	-.04
		Positive Ranks	4	4.25	17			
		Ties	0	-	-			

*p ≤ .05

According to the left leg, there was a significant decrease in Flex. maxTorque (*z* = -2.38, *p* = .02, *r* = -.60), Flex. peak power (*z* = -2.38, *p* = .02, *r* = -.60) and Ext. peak power (*z* = -2.24, *p* = .03, *r* = -.56), *p* < .05, and a non-significant decrease in Ext. maxTorque (*z* = -1.75, *p* = .08, *r* = -.44), Flex. maxTorque/weight (*z* = -1.36, *p*

$= .17$, $r = -.34$), Ext. maxTorque/weight ($z = -1.00$, $p = .32$, $r = -.25$), and Flex./Ext. ($z = -.14$, $p = .89$, $r = -.04$), $p > .05$, between pre- and post-test results (Table 4.36).

CHAPTER 5

DISCUSSION

The results of the study were discussed with thinking on the cause and effect relationship along with the related literature information, and the discussion was presented under the topics of body composition, sprint, jump, Wingate test and isokinetic strength test.

5.1. Body Composition

In none of the body composition parameters, namely, body weight (kg), BMI (kg/m^2), BFP (%), FM (kg) and LBM (kg), which were obtained through bioelectrical impedance analysis, was there a significant difference in the intergroup and intragroup comparisons (pre-test and post-test). It was seen that two different forms of plyometric training that were applied in the study did not lead to a significant difference in the body composition parameters.

In a similar vein, in another research, which studied the effects of a plyometric exercise for three days a week over a period of eight weeks, in neither plyometric nor plyometric + aerobic exercise groups was there a significant difference in body mass and fat percentage (fat %) in the intragroup and intergroup evaluation (Potteiger, Lockwood, Haub, Dolezal, Almuzaini, Schroeder, & Zebas, 1999). As in the present study, 8-week plyometric training did not cause any significant change in body composition in physically active men. Another similarity to the aforementioned study is that a limited number (just 4 exercises) of plyometric exercises were used. In yet another research study that was conducted on physical education students, even a six-week strength training combined with plyometric exercises did not result in a significant difference in the body mass and the fat percentage (Perez-Gomez et al., 2008).

In a study, which investigated the effect of plyometric training on different training volume and surface in untrained individuals, 7-week plyometric training showed no significant difference in body mass and BMI in any training groups (Ramírez-Campillo et al., 2013). In another study conducted on middle- and long-distance runners to investigate the plyometric training effects, there was no significant change in body mass and BMI (Ramírez-Campillo et al., 2014). Contrary to these studies, in the research study on physically active men, 2 different plyometric training programs, which were equalized in terms of training volume, were performed as 4-week and 7-week programs. The 4-week program made a 1.1% increase in body mass. The 7-week program provided a 1.1% increase from pre-test to immediately post-test and a 1.9% increase from pre-test to the fourth week following the post-test (Luebbers et al., 2003). Also, in a research study in which the effects of resistance training, plyometric training and complex training (a combination of RT and PT) on recreationally trained men were studied, there was a significant increase in the percentage of body fat in the RT group and PT group nine weeks after the pre-test. However, this increase was thought to be practically not significant and could be due to the diet of subjects (MacDonald et al., 2012). In contrast to these studies, in different research, performed in order to detect the effects of progressive resistance training and plyometric training in teenage boys, both resistance and plyometric training decreased the body weight, BMI and percent body fat compared to the control group (Sinikumar, Daniel, & Sreedhar, 2017). As opposed to also current study, the participants in the aforementioned study were between the ages of 15 and 18, the duration of the training was 12 weeks, the plyometric exercises that were used varied greatly, and the exercises aimed at improving the performance of both the upper extremities and the lower extremities (Sinikumar et al., 2017). A different study used 12-week strength training combined with plyometrics and reported 15.7% and 16.4% decreases in body fat mass and fat %, respectively. A 2.1% significant increase was seen in lean mass (Carvalho, Mourão, & Abade, 2014). In the present study, the fat mass showed a non-significant 10.14%reduction just in the hypoxia group. Also, there was a non-significant 8.17% decrease in body fat percentage and 1.14% increase in lean body mass only in the hypoxia group.

The results of the present study did not show a significant difference in body composition and are in line with the results of the other ones, which were limited to similar periods of time and exercise variety, among the previously mentioned studies in normoxia. However, in the longer-term plyometric training programs (like 12-week programs) or long-term plyometric+strength training programs, improvements in the body compositions were observed. Yet, in the current study, at the end of the eight-week training period, it was observed that there was an insignificant tendency to a decrease in the values of the body weight, BFP and FM, and an insignificant tendency to an increase in LBM only in the hypoxia group.

It was thought that this non-significant difference may be due to the hypoxia. Likely, there was a study conducted in normobaric hypoxia (4000m) and 6-week strength training led to a significant increase in protein synthesis and also in body mass and FFM (Chycki et al., 2016). However, contrary to this, Kon et al., (2014) found a significant increase in body mass and lean body mass, and a significant decrease in percent body fat after 8-week resistance training both in hypoxia and normoxia, but these differences were not significant between the two groups. Therefore, the differences cannot be attributed to the hypoxia in that study. On the other hand, Ho et al., could not find any significant changes in body weight, lean body mass and fat mass after 6-week resistance training in either hypoxia (2300m) or normoxia (Ho, Kuo, Liu, Dong, & Tung, 2014). Also, Inness et al. (2016), carried out a study on the effects of 7-week heavy resistance training in hypoxia (first 4 weeks at 3100m and last 3 weeks at 3400m) in trained men, and did not find out any significant change in body composition in intragroup and intergroup comparisons.

5.2. Sprint

In both training groups in the study, there was a significant decrease in 20 m sprint time. This decrease in the hypoxia group was 3.42 %, and it was 2.58 % in the normoxia group.

In the literature, researches investigating the effect of plyometrics on sprint are few and contradictory (de Villarreal, Requena, & Cronin, 2012). For instance, Perez-Gomez et al. (2008) and Thomas et al., (2009) found no significant difference in 20m sprint values in their studies.

Conversely, in a study conducted by Ramírez-Campillo et al. (2013), to investigate the effect of plyometric training on different training volume and surface in the untrained subject, only HVG group (high volume training group) showed a significant decrease in 20m sprint time. In another study investigating the effects of different frequencies and volume of plyometric training in untrained subjects, 7-week plyometric training leads to a significant decrease in 20m sprint time in all training groups (de Villarreal et al., 2008). In a different study, 8-week supplementary plyometric training significantly increased sprint speeds in athletes (for 0-5m acceleration phase and for 0-40m maximal speed phase) (Chelly et al., 2010).

8-week low-intensity high-volume plyometric training on female athletes induced a significant reduction in 20-m sprint time only in the training group (%8.1) (Ozbar et al., 2014). In another study applied to investigate the plyometric training effects, on middle- and long-distance runners, a significant decrease was detected in training group in 20m sprint time test after 6-week high-intensity moderate volume implementation (Ramírez-Campillo et al., 2014). In other respects, Arazi and Asadi, (2011) studied the effects of aquatic and land plyometric training in their research and found that both aquatic and land training groups achieved a significant decrease in 36.5m and 60m sprint time at the end of the 8-week training. However, no significant difference was found between aquatic and land groups (Arazi & Asadi, 2011).

It is thought that significant improvements in the present study may be related to exercise variety because the literature suggested that the use of DJ, CMJ and SJ exercises together may provide higher increments than the alone ones (de Villarreal et al., 2012). Also, during the first 4 weeks, the split squat jump was performed in this study. It is stated that the training programs including more horizontal acceleration may provide further improvement in sprint performance (de Villarreal et al., 2012; Markovic, Jukic, Milanovic, & Metikos, 2007). For example, in the study examining a 10-week sprint and plyometric training, just sprint group showed a significant improvement in 20m sprint test (3.1%) compared to both plyometric training and control groups (Markovic et al., 2007).

The majority of the development of untrained individuals during the first weeks of power-type strength training is possibly explained by adaptations in the neural system (de Villarreal et al., 2012). Therefore, all the aforementioned data account for the improvement in the 20 m sprint performance resulting from plyometric training, but the fact that it was higher in the hypoxia group leads to a possible hypothesis that hypoxia has a greater effect on neural adaptation. However, in a research investigating the effects of a 7-week heavy resistance training (3100 meters for the first four weeks, and 3400 meters for the last three weeks) in hypoxia on trained men, there was no significant difference in 20 m sprint time in the intragroup and intergroup comparisons (Inness et al., 2016). As for the present study, it is thought that the expected neural adaptation has been achieved when hypoxia was applied with plyometric training.

On the other hand, the effects of hypoxia on sprint has so far been manifested through repeated sprint training sessions. For instance, in a study investigating the effect of 4-week repeated sprint training in hypoxia (RSH) in female athletes, it was found that significantly greater improvement in repeated sprint ability was detected in the RSH group than the RSN group (Kasai et al., 2015). In another study, repeat-sprint training in hypoxia increased repeat sprint ability after six sessions in well-trained male rugby players (Hamlin, Olsen, Marshall, Lizamore, & Elliot, 2017). In a different study, it was concluded that RSA may be improved by shuttle-run sprint training in hypoxia, in relation to the lower fatigue slope, when compared to that in normoxia (Gatterer et al., 2014). Contrary to these, after 12 sessions of repeated sprint training over 4 weeks, Galvin et al., (2013) did not find a significant improvement in 5, 10, 20m sprint performance in hypoxia group (13% FiO_2) compared to normoxia group (in male athletes). On the other side, in the research studied by Brocherie et al. (2015), 5-week repeated sprint training in hypoxia (2900m), including also plyometric exercises, was applied on highly trained athletes. Although there was no significant difference in the 40m sprint test (for each 10m) between groups as in the present study, the RSH group showed greater improvement than RSN (Brocherie, Girard, Faiss, & Millet, 2015).

Also, there are local hypoxia training methods which mention their effects on sprint, in the literature. For instance, in a study applying a resistance exercise combined with blood flow restriction (BFR), which is a local hypoxia training, for 8 consecutive days of training in college athletes, a significant improvement was observed in overall 30-m sprint time in the BFR-training group, and significant development was seen just in the initial acceleration phase (0-10m) (Abe, Kawamoto, Yasuda, Midorikawa, & Sato, (2005). Another study performed to assess the effects of ischemic preconditioning (IPC), which is the other local hypoxia technique, in well-trained participants on split times of sprint at 10, 20, and 30 m, it was seen that there were no significant effects of the IPC on sprint speed at any of the split times (Gibson, White, Neish, & Murray, 2013).

In systemic hypoxia methods, it is known that RSH was generally used and provided improvements in repeated sprint ability. Indeed, the literature supports the significant improvements in sprint time or running velocity when using the plyometric exercises combined with sprint-specific types, and moreover, it has been stated that the training programs involving vertical plyometric exercises do not provide a significant improvement in sprint acceleration (de Villarreal et al., 2012). However, this study revealed significant improvements in sprint performance as a result of mainly vertical plyometric exercises and also this improvement was found greater when applied in systemic hypoxia contrary to the inconsistent results of the local hypoxia studies.

5.3. Jump

At the end of the 8-week training program, there was no significant difference in the jump test variables among the three groups; however, in the intragroup comparisons, significant differences were observed in two training groups, and the difference in the hypoxia group was striking.

In the hypoxia group, CMJ increased by 5.59 cm, showing significant improvement (by 14.80 %), whereas, in the normoxia group, this increase was 3.19 cm (8.55%), which is a significant improvement. In the control group, there was an insignificant increase of 0.73 cm (1.93%).

The results of this study are consistent with the plyometric training findings in the literature. For example, in the study conducted on athletes, vertical jump height significantly increased by 1.81 cm after 3-week plyometric training (Roopchand-Martin & Lue-Chin, 2010). In a different study that uses a 6-week training period consisting of DJ and CMJ exercises, there were no significant differences between two different plyometric groups as in our study, but significant improvement occurred in the vertical jump height with the exercise. DJ training generated a significant effect size of 1.1. CMJ training produced a moderate-high effect size of 0.7 (Thomas et al., 2009). On the other hand, in a research which studied the effects of different frequency and volume of plyometric training in untrained individuals, four separate groups were formed: control, 7S (7 sessions of DJ training, 1 day/week), 14S (14 sessions of DJ training, 2 days/week), and 28S (28 sessions of DJ training, 4 days/week). The 7-week training program led to significant increases in CMJ (17.48% for the 28S group and 11.09% for the 14S group) (de Villarreal et al., 2008). It is thought that CMJ height in the mentioned study is higher than the development rate of the normoxia group in the present study and this can be due to the training content. While 4 different plyometric exercises were used during the present study, only DJ exercise was used in the above-mentioned study. And, according to the results of a meta-analysis, it is reported that there is better development of VJH (Vertical Jump Height) with high-intensity training. It has been stated that VJH is higher in DJ, then CMJ and finally in SJ (de Villarreal et al., 2009). However, when it is applied under hypoxic conditions, it can be seen that the current study achieved similar results (14.80%) to the results of the aforementioned study. Moreover, DJ is a high-intensity plyometric exercise. Whereas the 28S group carried out 1680 DJs in total and the 14S group carried out 840 DJs in total, which caused a much greater amount of stress on the neuromuscular system, the current study has achieved a similar result by applying a smaller number of DJ.

Contrary to the current study, there are also plyometric studies that have negative effects on CMJ, in the literature. For instance, in a study investigating the effect of plyometric training on different training volume and surface in the untrained subject, plyometric training led to significant decrease in CMJ when applied with a high training volume or with a moderate volume on a hard surface (moderate volume+hard surface) (Ramírez-Campillo et al., 2013). In a different study on physically active men, 2 different plyometric training programs, which were equalized in terms of training volume, were performed as 4-week and 7-week programs. In the 4-week training group, a significant decrease (3.5%) from pre to post-test was found in vertical jump height. As for the 7-week training group, a nonsignificant decrease (0.3%) from pre to post-test was detected (Luebbers et al., 2003). These decreases in VJH (vertical jump height) may result from overtraining because in the same study after allowing 4 weeks recovery significant increase was observed in VJH (Luebbers et al., 2003).

As well as the studies where only the plyometric training is used, there are some studies where additional plyometric training is used in addition to their own training. 8 weeks of supplementary plyometric training significantly increased the height of CMJ at the rate of 4.2% (Chelly et al., 2010). In another study which is examining the impact of 6 weeks of plyometric training on the male distance runners, the pre and post-test values at the CMJ height demonstrated the significant difference of the training group while the control group did not demonstrate such difference. In the training group, CMJ height demonstrated a 13.2% increase (Spurrs et al., 2003). 8 weeks of low intensity, high volume plyometric training conducted on the female athletes demonstrated significant change in CMJ height both in the control and training groups who also continue to the football training. There was a 17.6% increase in the training group and 6.9% increase in the control group at CMJ (Ozbar et al., 2014). As can be seen, plyometric training sessions that are carried out in addition to athletes' regular training programs contribute to important improvements in the increase in CMJ. Although there was only a plyometric training program in the current study, there was a big improvement in the hypoxia group, which was similar to the improvements in the additional plyometric training programs in other studies.

On the other hand, another method where plyometric training is used in the literature research is combining the plyometric exercises with different training types. For instance, in a study examining the 8 weeks of plyometric exercise impacts on the physically active men, there was no significant difference between the groups. However, the vertical jump height (2.7 cm) increased by 4.6% in the group which was doing plyometric training while it increased by 5.0% (3.1 cm) in the group which was doing both plyometric training and aerobic exercise (Potteiger et al., 1999). The plyometric training applied under normoxic conditions in the current study showed more improvement than the one in the study of Potteiger et al., (1999) while it is clearly seen in the current results that more improvement was achieved when the same training is carried out under the hypoxic conditions. Moreover, in another study examining the impacts of weight training (W), plyometric exercise (P) and their combination (C) on the untrained men, P group significantly increased the vertical jump height by 6 cm, W group increased by 5.4 cm and C group increased by 8.6 cm. Combination training group demonstrated significantly better performance than P and W (Fatouros et al., 2000). In a study conducted over the male handball players, a 12-week additional combined plyometric and speed training program showed a significant increase by 2.78% at CMJ (Cherif et al., 2012). In another study where weight and plyometric training were combined, the effects of 6-week squat training, plyometric training and squat-plyometric training was examined on the intermediate lifters and, S group increased the vertical jump by 3.30 cm, P group by 3.81 cm and SP group by 10.67 cm (Adams, O'Shea, O'Shea, & Climstein, 1992).

As is seen, the improvements in the results of plyometric training studies combined with weight training and sprint training vary. In a meta-analysis, it is stated that VJH development is not better when combined with other exercise types such as resistance, aerobic exercise, flexibility exercise and water exercises (de Villarreal et al., 2009).

It has been reported that plyometric training contributes to an increase between 4.7% and 15% in VJH because of the increased muscle power and coordination as a result of training. On the other hand, in the literature, there are studies that didn't find significant improvement as well as some other ones that found a negative impact on VJH (de Villarreal et al., 2009). However, in the current study, the significant improvement in both the normoxia group (8.55%) and the hypoxia group (14.80%) are remarkable figures when evaluated in terms of the percentages. Although the same exercise program (with the same number of repetitions and set) was applied for the same period of time in both of the training groups, the rate of improvement was quite different. In the study hereby, the effect of the combined training was found to be greater just like the weight training+plyometric exercises in the studies of Adams et al. (1992) and Fatouros et al. (2000), yet without spending extra time on the additional training type and without dealing with heavy lifting during the training. The reason for this is that in the current study, the hypoxia group underwent exactly the same training by wearing a mask.

As for the squat jump performances, the hypoxia group improved significantly by an increase of 5.69 cm (16.06%), whereas in the normoxia group this increase was 3.17 cm (8.83%), which was not statistically significant. On the other hand, in the control group, there was an insignificant decrease of 0.01 cm (0.03%). It is evident in the results that the same training program leads to further improvements when performed under hypoxic conditions. The effects of plyometric training in normoxia conditions on SJ are varied. In a study made on male handball players a 12-week additional combined plyometric and speed training did not show a significant difference in SJ between pre- and post-test results (Cherif et al., 2012), while another 8-week supplementary plyometric training significantly increased the SJ height (7.1 %) in athletes (Chelly et al., 2010). As a result of the 6-week plyometric training carried out among the adolescent badminton players, squat jump demonstrated a significant increase in the plyometric group (26% and medium effect size) and control group athletes (10%, small effect size). A significant difference was found between control and plyometric group (Özmen & Aydoğmuş, 2017). In another study which is examining the different training volume and surface effect of the plyometric training, a significant increase was observed only in the moderate volume group (Ramírez-Campillo et al., 2013).

The height of the drop jump showed a significant increase of 5.24 cm (15.97%) in the hypoxia group, while there was an insignificant increase of 2.73 cm (7.89%) in the normoxia group. The control group showed an insignificant decrease of 1.47 cm (4.34%). The DJ ground contact time represented a significant increase, with 11.87 ms (5.36%) in the hypoxia group, whereas it saw an insignificant decrease, with 4 ms (1.76%) in the normoxia group. In the control group, there was an insignificant increase, with 6.38 ms (2.93%). The RSI value improved significantly, with an increase of 0.15 (10%) in the hypoxia group. There was an insignificant improvement in the normoxia group, with an increase of 0.15 (9.38%). On the other hand, the control group showed an insignificant decrease of 0.08 (5.26%). The jump height in the hypoxia group showed greater improvement compared to the normoxia group. Typically, the ground contact time is expected to be low and the jump height is expected to be high for success in RSI. In the study hereby, the contact time for the hypoxia group was found to be significantly high, but despite this, the RSI value showed a significant improvement only for the hypoxia group. It is assumed that this improvement stems from the significant increase in the jump height. Furthermore, this result may indicate that the individuals in the hypoxia group focused more on the jump height rather than the contact time during the test. The results mentioned above seem in parallel with a study investigating the effects of different instructions on performance. In the said study, DJ was applied with three different sets of instructions. The instructions were given in three different ways for maximum jump height (DJ-H), minimum contact time (DJ-t) and maximum jump height/contact time ratio (DJ-H/t). In the said study, when the individuals were prompted to jump to the maximum height in the minimum contact time, the mean contact time decreased by 56-57% compared to DJ-H. When there was less time for force production, the jump height decreased significantly, by 18-21% compared to DJ-H. When the individuals were warned specifically about the short contact time (DJ-t), mean contact time saw a significant decrease of 17-20% compared to DJ-H/t, and the jump height dropped dramatically, by 62-70% (Young et al., 1995).

It is known that plyometric training in normoxic conditions have positive effects on RSI and Drop jump performance. For instance, in the study examining the plyometric training effects on middle- and long-distance runners, the reactive strength values obtained from DJ20 and DJ40 significantly changed in training group (Ramírez-Campillo et al., 2014). In the research which studied the effects of different frequency and volume of plyometric training in untrained individuals, 7-week training program led to significant improvements in the height of 20-, 40-, 60-cm DJs and significant decreases in contact time in the training groups (de Villarreal et al., 2008). In the study made by Ramírez-Campillo et al. (2013), to examine the effect of plyometric training on different training volume and surface in the untrained subject, RSI value obtained from 20-cm drop jump performance showed a significant increase in the group that used moderate-volume and hard surface and also in the group that performed the training with high-volume. As for the 40-cm drop jump, there was a significant increase only in the group that used moderate-volume and hard surface (Ramírez-Campillo et al., 2013). In another study where sprint and plyometric training was implemented 3 days in a week for 10 weeks, DJ performance of both the sprint group and the plyometric group demonstrated a significant increase when compared to the control group (Markovic et al., 2007). On the other hand, Andrade et al., (2018) found that 4-week plyometric training significantly increased the sea level RSI value and this improvement could be maintained in acute hypoxia as well. In the current study, both training groups demonstrated development in RSI; however, this development is statistically significant only in the hypoxia group.

Overall, when the jump performance is considered, it can be observed that in the study hereby, the normoxia group improved significantly only in the CMJ while the hypoxia group improved significantly in all the jump tests. In another study investigating the effect of 6-week strength training combined with plyometric exercises, while a significant improvement was not observed in squat jump, it was seen in the CMJ jump (Perez-Gomez et al., 2008). In another study which was examining the impacts of plyometric and weight training, plyometric training significantly increased the jump height in SJ, CMJ and DJ while WT group increased only in SJ (Kubo et al., 2007). In a study using different plyometric training exercises, a significant increase was observed only in the heights of SJ and CMJ following a 12-week program in CMJ training group, a significant increase was observed in the SJ, CMJ and DJ heights in the DJ training group (Gehri, Ricard, Kleiner, & Kirkendall, 1998).

While in some studies the rate of improvement varies depending on the amount of strength and plyometric exercises (Kubo et al., 2007; Perez-Gomez et al., 2008), in some other studies a long period of time and high-intensity training is required for improvement (Gehri et al., 1998). In the case of the study hereby, the jump height nearly doubled with the addition of hypoxia factor to the same training that was applied in the normoxia group.

On the other hand, the results obtained from the training methods excluding the plyometrics in hypoxia vary. While local hypoxia did not contribute to the jump performance (Abe, Kawamoto, Yasuda, Midorikawa, & Sato, 2005; Haruhiko, Ochi, Tomioka, Nakazato, & Ishii, 2011; Ismail, 2014), repeated sprint training in hypoxia that included explosive power exercises led to greater improvements in the hypoxia group compared to the normoxia group, just like in the present study (Brocherie et al., 2015).

In the study conducted by Haruhiko et al., (2011) the effect of blood flow-restricted training (BFRT) twice a week for 10 weeks was tested on jump performance and CMJ height did not change after the training. Abe et al., (2005) performed a resistance exercise combined with blood flow restriction (BFR) for 8 consecutive days of training in college athletes in their study, and there is no significant improvement in jump performances either BFR group or Control group.

In a study testing the effectiveness of strength training, blood flow restriction and their combination over 7 weeks in elite athletes, no significant change was observed in countermovement jump in any of three training groups (Ismail, 2014).

In the hypobaric environment, 4-week strength training was applied and plyometric exercises were used in that strength training. Strength training in hypoxia produced a non-significant increase (4.33cm) in SJ and (2.11cm) in CMJ. The group that performed the same training protocol in normoxia exhibited a non-significant increase (1.89cm) in SJ and (3.26cm) in CMJ (Álvarez-Herms et al., 2014). Contrary to the aforementioned results, the study hereby - as the first study that has applied plyometric training under hypoxic conditions- revealed significant improvements in both of the training groups, with a higher increase in the hypoxia group.

In the research studied by Brocherie et al., (2015) 5-week repeated sprint training in hypoxia (2900m), including also plyometric exercises, was applied on highly trained athletes and the RSH group presented greater magnitude in CMJ height compared to the RSN. No significant difference was found between the groups, but there was a significant increase in lower-limb explosive power in both groups (Brocherie et al., 2015). While, in a meta-analysis, it was stated that VJH improvement did not yield better results when it was combined with other types of exercises (de Villarreal et al., 2009), in the present study it was observed that the combination of plyometric training with hypoxia contributed significantly to the improvement in the jump performance.

5.4. Wingate Test

Wingate test results showed no significant difference among the three groups, however, significant changes were observed between pre- and post-test results in both training groups. The peak power of hypoxia group increased by 60.53W (7.72%), while the increase in normoxia group was 46.14W (6.09%). The relative peak power increase was 0.89 W / kg (7.89%) in the hypoxia group and 0.81 W / kg (7.05%) in the normoxia group. Increases in both groups were statistically significant. In the control group, a non-significant decrease of 10.79 W (1.39%) in peak power and a non-significant increase of 0.13 W/kg (1.16%) in relative peak power were observed.

Average power showed non-significant changes in all groups. These changes were an increase of 24.64 W (4.32%) in hypoxia group, an increase of 43.27 W (8.32%) in normoxia group and a decrease of 2.58 W (0.47%) in control group. As for the relative average power, the hypoxia group showed a non-significant increase of 0.36 W / kg (4.41%) while a significant increase of 0.79W / kg (10.06%) was found in the normoxia group. The control group showed a non-significant increase of 0.15 W / kg (1.87%).

Min. power value increased by 21.16 W (6.30%) and 8.53 W (2.77%) in hypoxia group and normoxia group, respectively, and decreased by 2.55 W (0.85%) in the control group. All these changes were not statistically significant. Relative min. power value showed non-significant increases of 0.35 W / kg (7.38%), 0.20 W / kg (4.30%) and 0.09 W / kg (2.04%) in the hypoxia group, normoxia group and control group, respectively.

The value of power drop (%) indicated non-significant changes in all groups. Power drop (%) decreased from 57.55 to 57.23 in the hypoxia group and showed a non-significant 0.56% decrease. It increased from 59.51 to 60.22 in the normoxia group and created a non-significant 1.19% increase. In the control group, it decreased from 60.52 to 59.80 with a non-significant 1.19% decrease.

The value of the decline in power showed non-significant differences in all groups. These differences were an increase of 36.62 W (9.13%) in hypoxia group, an increase of 21.03 W (4.88%) in normoxia group and a decrease of 16.98 W (3.79%) in control group.

These findings were in accordance with the results of the study by Reyment et al. (2006) in that study, testing the impacts of 4-week plyometric training on hockey players, no significant difference was found in the variables of minimum power and relative minimum power while anaerobic peak power (increased) and relative peak power (increased) demonstrated significant differences. Only the finding of power drop percentage was different from the present study result. A significant decrease was observed in the percentage of power drop according to the results of the Wingate test (Reyment, Bonis, Lundquist, & Tice, 2006).

Actually, it is known that plyometric training is used as a popular method to improve jump performance and anaerobic power (Luebbers et al., 2003). For instance, the study, applying 10 weekly plyometric training on judokas, supports too that plyometric training demonstrated significant development on the anaerobic power (Uzun & Karakoc, 2017). Another study by Wagner and Koçak (1997) revealed that 6-week plyometric training significantly increased lower body anaerobic power. This power increase obtained from Margaria-Kalamen test, from pre- to post-test, was 17.7% in nonathletic plyometric group and was 19.4% in the athletic plyometric group (Wagner & Kocak, 1997). In the different study applied on physically active men, 2 different plyometric training programs were equalized in terms of training volume and performed as 4-week and 7-week programs. After 4-week training, there was a non-significant increase but after 7-week training the increase was significant in anaerobic power measured by the Margaria Staircase test. Also, after giving a 4-week recovery, both training groups significantly increased the anaerobic power (Luebbers et al., 2003). In the study examining the effect of 6 weeks plyometric high and low-intensity training in volleyball players, the training programs applied to both groups were found to be effective in the development of the maximal power measured by the Wingate test, also the high-intensity group showed a greater improvement (Jastrzebski, Radziminski, Jaskulska, Mikolajewski, & Wnorowski, 2014).

As it is seen, the positive impacts of plyometric training are observed both in trained and untrained individuals (Wagner & Kocak, 1997) and it is informed that when it is applied for longer periods (> 6week) or at more high intensity (Jastrzebski et al., 2014), it produced better improvement. However, contrary to these, there are studies, which do not include significant development.

For instance, in the study on male physical education students to detect the effects of 6-week weight lifting training combined with plyometric exercises, a non-significant increase was observed in peak power and mean power at the Wingate test (Perez-Gomez et al., 2008). In another study comparing the effects of plyometric training and traditional weight training after 6-week training period, plyometric training group showed insignificant increase in peak power and mean power, whereas weight training group significantly increased the mean power and produced non significant increase in peak power (Brown, Wells, Schade, Smith, & Fehling, 2007).

In the present study, the plyometric training applied both under hypoxic and normoxic conditions demonstrated significant improvement in peak power and relative peak power. It is seen that both plyometric exercises and hypoxia have impacts on anaerobic performance. As it is seen, peak power and min power values are greater in hypoxia group while average power is better in the normoxia group. In conformity with the present study, in a study investigating the effect of hypoxia training on repeated sprint performance (on female athletes), after 4 weeks of hypoxia (3000m) and normoxia training, hypoxia group represented significant greater development in repeated sprint test than normoxia group. During repeated sprint test, a nearly three-fold greater increase was detected in peak power output in the hypoxia group than in the normoxia group. However, in that study, the applied training is already repeated sprint training (Kasai et al., 2015), but in the present study, plyometric training was practiced and similarly greater improvement was observed in the peak power in the hypoxia group.

Likewise, Meeuwsen et al., (2001) applied a 10-day intermittent hypobaric hypoxia (2500m) training on elite male athletes, and found that mean power (W), relative pean power (W/kg), peak power and relative peak power (W/kg) were significantly increased 9 days after the intervention just in the hypoxia group. A different study, conducted with the aim of evaluating the anaerobic capacity as a result of 4-week endurance strength training at simulated altitude (2500 m), examined the anaerobic capacity by sixty seconds repeated maximal countermovement vertical jump (60CMJ) and found significant development in hypoxia group compared to the normoxia training group (Álvarez-Herms et al., 2014). In the study investigating the effects of 4-week high-intensity circuit strength training in hypoxia (3000 m) on the anaerobic running performance, the circuit training in hypoxia improved the anaerobic performance of athletes (Álvarez-Herms, Julià-Sánchez, Corbi, Pagès, & Viscor, 2016).

In contrast to the present study, the hypoxia group was found better at average power and the normoxia group was better at peak power in the study of Morton & Cable (2005). In that study of Morton & Cable (2005), it was aimed to detect the effects of 4-week (12 sessions) short-term intermittent hypoxic training (2750 m) on sea level aerobic and anaerobic performance in moderately trained subjects. 4 weeks of moderate-to-high intensity IHT led to similar increases in anaerobic performance when compared to equivalent sea level training. In accordance with the current study, in that study there was no significant difference between the training groups, but significant increases were found at different rates in pre- and post-test results of normoxia and hypoxia groups. According to Wingate results, peak power increased in the normoxia group by 8.5% and in the hypoxia group by 2.1%. Relative peak power (W/kg) also increased in normoxia (9.3%) and in hypoxia (2.9%). As for the mean power, normoxia group improved by 6.1% and hypoxia group improved by 6.5%. In terms of the relative mean power the increase was 6.5% in the normoxia group and 8.0% in the hypoxia group. All pre- and post-test differences were significant.

Similarly, the study of Hamlin et al. (2010) researched the effect of intermittent hypoxic training on 30 s anaerobic performance. 90 minutes endurance training followed by two 30-s all-out sprints, daily, for 10 sequential days (altitudes, on days 1-2, 3-4 and 5-10, were 3200m, 4000m, and4400 m, respectively) was executed by trained athletes. It was found that 10 consecutive days of IHT substantially improved anaerobic power during the Wingate test. The hypoxia training revealed a 3.0% improvement in mean power. In a different study conducted on trained male cyclists, a 4-week (8 sessions) repeated sprint training was performed in hypoxia (3000m) and in normoxia (485m). Wingate test performance showed no significant difference between hypoxia and normoxia groups. Mean power (W) revealed a significant increase in both hypoxia and normoxic group, but no significant difference was found in the control group (Faiss, Léger, et al., 2013).

Contrary to these and the present study results, Tadibi et al., (2007), studied short-term (15 consecutive days) intermittent hypoxic exposure in their research and found that 1 h of intermittent hypoxic treatment did not make an improvement in peak power and mean power obtained by Wingate anaerobic test. No significant difference was found between hypoxia and control groups.

As stated before, altitude does not impair the anaerobic activities and can even improve them (Kenney et al., 2011) because acute hypoxia has no effect on anaerobic alactic or lactic energy production (Wolski et al., 1996). Therefore anaerobic performances, lasting shorter 2 min, are not affected by the low PO_2 (Fox et al., 1988; McArdle et al., 2009; Powers & Howley, 1996). In the study applied by Friedmann et al., (2007) to analyze the effects of acute (4 h exposure) moderate normobaric hypoxia (2,500m) on anaerobic capacity in endurance-trained runners, it was supported that anaerobic capacity is not affected by acute hypoxia exposure. It was reported anaerobic energy release may be increased during all-out exercises of between 40 and 120 seconds (Friedmann et al., 2007).

In the current study, plyometric training was high-intensity training. And, it is known that high-intensity actions need a high level of anaerobic power and short term maximal force production (Álvarez-Herms et al., 2014). Therefore, this can be regarded as the reason for plyometric training effect, but in terms of the hypoxia effect, there are some different potential reasons. At altitude, it was stated the improvements in anaerobic exercise performance most probably depend on the reduced effect of drag in association with the thinner air. Drag is the resistance to a body moving in the air or in water (Hoffman, 2002). However, in the current study the improvements in anaerobic power can not result from the reduced drag effect because of the normobaric hypoxia implementation (not a real altitude), but it can be due to the further stimulation of the anaerobic metabolism and increased energy production by anaerobic pathways (Álvarez-Herms et al., 2014). In addition, the literature suggests the enhanced muscular buffer capacity as a reason for anaerobic performance improvement (Álvarez-Herms et al., 2014). Therefore the difference in anaerobic peak power between the hypoxia and normoxia group may be due to the enhanced muscular buffer capacity and improvements in anaerobic metabolism, not due to a potential increase of the training intensity resulting from the hypoxia, because the workload of the training was identical for both hypoxia and normoxia groups and the literature suggest that anaerobic performances are not affected by the low PO_2.

5.5. Isokinetic Strength Test

The results of the isokinetic strength test revealed differences in the comparisons of both intragroup and intergroup.

According to the measurement made at the speed of 60°/sec, a significant difference was observed in the Flex. peak power (W) in the right leg just between hypoxia (103.25±14.24) and control group (82.38±15.83). The Flex. peak power value of the hypoxia group was significantly higher compared to the control group. In the left leg, a significant difference was found in the Ext. maxTorque/weight only between hypoxia (3.02±.27) and normoxia (2.22±.80) groups. It is seen that the relative Ext. maxTorque value of the hypoxia group is significantly higher than the normoxia group.

In the comparison of pre- and post-test, Flex. maxTorque of right leg increased by 15.69% in the hypoxia group while it increased by 11.93% in normoxia group while decreasing by 1.52% in the control group. Only the increase in the hypoxia group was significant. Moreover, again only in hypoxia group right leg Flex. peak power value increased significantly (18%) while the normoxia group showed an insignificant increase (13.35%). On the other hand, the control group showed a significant decrease in the right leg in Ext. maxTorque value and, in the left leg in Ext. maxTorque, Ext.maxTorque/weight and Ext. peak power values.

As for the measurements at the speed of 180°/sec, a significant difference was observed in the value of Flex. maxTorque/weight in the right leg just between the hypoxia and control group. Flex. maxTorque/weight (1.72±.24) value of the hypoxia group was found significantly higher than the control group (1.41±.20). In the left leg, Flex. peak power value was observed significantly higher in hypoxia group (196.25±42.33), than both normoxia group (155.57±16.04) and control group (156.50±15.86). Moreover, Ext. peak power value showed insignificant (p= .02) but the big difference between the hypoxia (250.63±49.41) and control (191.50±35.65) group according to the Bonferroni result ($p > .017$).

In the pre- and post-test comparison, only the hypoxia group (12.30%) presented a significant increase in Flex. peak power value in the right leg while normoxia group (5.57%) demonstrated an insignificant increase. Moreover, the control group demonstrated a significant decrease in Flex. maxTorque, Ext. maxTorque, Flex. peak power and Ext. peak power values in the right leg and, in Flex. maxTorque, Flex. peak power and Ext. peak power values in the left leg.

In the study conducted to investigate the effect of eight weeks plyometric training in basketball players, significant differences were detected in hamstring and quadriceps maxTorque values as a result of the training, but intergroup differences were found just in the right leg in both hamstring and quadriceps at both speeds of 60°/s and 180°/s. Also between the groups, no significant difference was obtained in hamstring/quadriceps ratios in right and left leg at both speeds, in parallel to the current study. Therefore it was understood that the improvements in hamstring/quadriceps ratio values and left leg maxTorque values were due to the Basketball training, not just plyometric training in that study (Adıgüzel, 2017).

Using plyometric training in order to improve strength and power is accepted by the literature (Tsang & DiPasquale, 2011). For instance, in a study investigating the effect of plyometric training on knee extension and flexion isokinetic strength in basketball players, 8-week (addition to basketball) plyometric training resulted in an increase in knee flexion and extension concentric isokinetic peak torque values of 60°/sec and plyometric training performed three days a week was found to be more effective than that performed once a week (Sağıroğlu, Önen, Ateş, Kayatekin, Şemin, 2003). In a different study, the effect of plyometric exercises in addition to tennis training on the isokinetic strength profiles of tennis players' knee extensors and flexors was investigated. At the end of 8 weeks, right knee extension peak torque at the speed of 60°/sec increased in both groups, but it was significantly higher in the experimental group since the 4th week. In addition, right knee extension and left knee flexion peak torque values at 120°/sec and left knee extension peak torque values at 180°/sec showed similar improvement in both groups. Briefly, in that study, plyometric exercises applied in addition to classical tennis training had positive effects on knee flexion and extension strength (Ölçücü et al., 2011).

In another study applied to detect the effects of 8-week plyometric and basic resistance training in female athletes, peak quadriceps torque at 60°/sec and 180°/sec increased in both training groups, while no significant improvement was found in hamstring strength (Hamstring torque increased nearly 6-7%) (Lephart et al., 2005). But in that study there was not a control group, and all subjects were female athletes and participated in basketball or soccer club teams (Lephart et al., 2005). Therefore the improvement of quadriceps strength may be due to the combination effect of basketball and plyometrics, but in the present study a control group was available and plyometric training applied in hypoxia showed significant improvements compared to the control group.

As it is seen in the above studies, the combination training effect is better to improve the strength, also in the present study the combination of plyometric and hypoxia showed greater improvement in strength changes. It is seen that the hypoxia group is better at Flex. peak power than the control group and at relative Ext. maxTorque than normoxia group at the speed of 60°/sec. In terms of pre-post comparison, only hypoxia group showed significant improvements in Flex. maxTorque and in Flex. peak power. As for the 180°/sec, relative Flex. maxTorque was significantly higher in the hypoxia group than control group, and Flex. peak power was significantly higher again in the hypoxia group than both normoxia and control groups. According to pre-post comparison, Flex. peak power significantly improved in just the hypoxia group. Actually, strength gains obtained from plyometric training are related to the stretched quadriceps muscle during the preparatory phase of jumping, before the contraction (Tsang & DiPasquale, 2011). However, in the present study the training mostly showed developments in hamstring strength. In accordance with this finding, Tsang & DiPasquale (2011) reported a similar result in their research. In that study plyometric training improved hamstring strength while remaining the quadriceps strength.

The higher improvement in hamstring strength than quadriceps in the present study may be due to the fact that subjects did not focus too much on jumping higher during the training programs. The reason for this, during jumping the takeoff movement requires active contraction of especially quadriceps group muscles (Aktuğ, 2013). On the other hand, in a study investigating the effects of 8-week training, which uses different squat protocols, on knee flexion and extension strength development, squat exercises were applied with the weight of 60% of 1RM. Measurements were taken at the velocities of 60 and 180º/sec. Significant improvements were detected in ext. and Flex. peak torque variables both at 60 and 180º/sec. Furthermore, it was observed that the knee which performs flexion showed more improvement in the mean power than the knee which executes extension (Akkoyunlu, Şenel, & Eroğlu, 2006).

On the other hand, ideal knee joint function depends on the optimal muscle functioning of quadriceps and hamstring rather than the strength of them. The hamstring-to-quadriceps (H/Q) strength ratio is used for the evaluation of knee functioning performance (Düzgün, Kaya, Baltacı, Karacan, Çolakoğlu, 2017). Also, an imbalance in this ratio can lead to lower extremity injuries (Andrade et al., 2012). Therefore at least 0.6 is recommended as an ideal H/Q ratio to prevent knee injuries (Dorgo, Edupuganti, Smith, & Ortiz, 2012; Düzgün et al., 2017).

Dorgo et al (2012) found that H/Q ratio improved as a result of a 12-week systematic lower-body resistance training (6–10 RM) and far exceeded the recommended ratio (0.6) in men and women. However, in the present study, the improvements in ratio were achieved by plyometric training especially in hypoxia.

In the present study, at 60°/sec, H/Q ratio increased from .56 to .63 (12.5%) in hypoxia group, it increased from .60 to .64 (6.67%) in normoxia group and from .55 to .60 (9.09%) in control group, in right leg. As for the left leg, it improved from .60 to .62 (3.33%) in hypoxia group, .63 increased to .64 (1.59%) in normoxia group and from .63 to .73 (15.87%) in control group. As for the 180°/sec, the ratio increased from .73 to .76 (4.11%) in hypoxia group, from .69 to .74 (7.25%) in normoxia group and it showed changes from .73 to .71 (2.74%) in control group, in right leg. It changed from .75 to .78 (4%) in hypoxia group, from .74 to .80 (8.11%) in normoxia group and from .77 to .76 (1.30%) in control group, in the left leg. When looking at these results in perspective, it is seen that the changes in the control group are due to the decrease in quadriceps strength, whereas the best advances in the ratio are in the hypoxia group because the changes in the normoxia group are also partly due to the decrease in quadriceps strength.

While plyometric training facilitates the rapid excentric force developments, heavy resistance training simplifies the concentric muscle functions (Wilson, Murphy, & Giorgi, 2009). It is reported that eccentric training leads to improvement in concentric strength owing to the increased neural activation and muscle hypertrophy, (especially in type II fibers) (Tsang & DiPasquale, 2011). Similar reasons were also reported for the local hypoxia-induced improvement. For instance, the study of Abe et al., (2006) concluded that the slow walk training with leg muscle blood flow restriction produced muscle hypertrophy and strength gain. Likewise, the study of Takarada et al., (2000) supports the hypertrophy and strength increase as a result of resistance training at intensity even lower than 50% 1RM when combined with vascular occlusion. In another study of Takarada et al., (2002) increases in muscle size, strength and endurance were observed in almost fully trained athletes resulting from an 8-week implementation of low-intensity resistance exercise combined with vascular occlusion. In another study in which the effects of low-intensity exercise with BFR on muscular fitness were investigated, BFR was applied with single-leg, and 5-min step exercise was performed three times a week for 5 weeks. The strength of the occluded leg significantly increased more than the nonoccluded leg (Teramoto & Golding, 2006). In another study applied to examine the effect of walking exercise with BFR in elderly individuals, a 20-minute walk was performed at a rate of 45% of the heart rate reserve for 4 days a week during 10 weeks and walking with BFR increased both muscle mass and strength (Ozaki et al., 2011). In the study of Manimmanakorn et al., (2013) the effects of a low-load (20% of 1RM) resistant exercise with BFR and also in normobaric hypoxia (SpO_2 at nearly 80%) were tested and it was observed that the resistant exercise led to substantial muscle strength and endurance improvements when combining with BFR or normobaric hypoxia.

The reason for strength development resulting from hypoxic or ischaemic conditions was mostly attributed to the increase of type II motor units recruitment. Hypoxia/ischemia-induced fatigue in type I fibers leads to recruitment of type II fibers (Manimmanakorn et al., 2013; Park et al., 2010). The reason for this is the occurrence of preferential recruitment rather than the size principle in these situations (Loenneke et al., 2010; Manimmanakorn, Manimmanakorn et al., 2013; Takarada et al., 2000). Another potential reason is the increase in growth hormone (Teramoto & Golding, 2006). In brief, primary mechanisms, that provide muscular strength and hypertrophy by the BFR exercise, are stated as metabolic accumulation, type II fiber recruitment and increased protein synthesis (Kawada, 2005; Loenneke et al., 2010).

As for the systemic hypoxia studies, in the study which examines the effects of 4-week low-resistance/high-repetition strength training in severe hypoxia (4500m), it was found that training in severe hypoxia did not produce more advantages than the equivalent normoxic training in terms of maximal strength and hypertrophy (Friedmann et al., 2003). In another study conducted to determine the effects of short-term resistance training with systemic hypoxia, 6 weeks of squat exercise training was performed on resistance-untrained men and no additive beneficial effects were found for greater strength and hypertrophy gains in hypoxia group compared to the normoxia group (Ho et al., 2014).

Contrary to those studies, in a study made to test the effects of 6-week resistance training (70% of 1RM) under intermittent systemic hypoxia (oxygen concentration at 16.0%), strength significantly increased at the end of the 6 weeks in both groups. Furthermore, it was seen that hypoxia accelerated the strength increases because strength significantly increased at the end of the third week in only the hypoxia group (Nishimura et al., 2010). In addition, a different study investigating the effects of different levels of systemic hypoxia with 5-week resistance training, also concluded RTH produced better improvement in strength and hypertrophy, and recommended the moderate-intensity (70% 1RM) resistance training under hypoxia (FiO_2 of 12.6%) to obtain the strength gains (Yan, Lai, Yi, Wang, & Hu, 2016). In that study resistance exercise in hypoxia led to the greater acute elevation of GH compared to that in normoxia, and is was stated that H+ accumulation during exercise in hypoxia might be the major stimulating factor for contribution to GH secretion (Yan et al., 2016).

As it is seen, although there were studies which found no significant additive effects of hypoxia in strength or hypertrophy gains (Friedmann et al., 2003; Ho et al., 2014), the reasons for the gains were regarded as again increase in growth hormone and recruitment of type II fibers such as local hypoxia (Yan et al., 2016). However, it is thought that the knee flexion and extension strength improvement seen in the hypoxia group in the present study may be owing to the neural developments. The literature suggests that the muscle strength gains are affected by neural factors and hypertrophy, and not just mechanical stress produces strength; metabolic, hormonal and neuronal factors also lead to improvement (Nishimura et al., 2010).

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

In this study, 8-week plyometric training in hypoxia did not provide a significant change in body composition, while it showed a higher rate of development in jump and sprint values than normoxia.

For the body composition variables, at the end of the eight-week training period, it was observed that there was an insignificant tendency to a decrease in the values of the body weight, BFP and FM, and an insignificant tendency to an increase in LBM only in the hypoxia group. It was thought that this non-significant difference in the study, which was seen only in the PTH, may be due to the hypoxia and hypoxia-induced protein synthesis because literature supports that strength training in normobaric hypoxia may led to a significant increase in protein synthesis and increase in FFM (Chycki et al., 2016). If the training period of this study was longer than 8 weeks, there could be significant differences in body composition because improvements in the body compositions were observed in the longer-term plyometric training programs (like 12-week programs) in the literature (Sinikumar, 2017; (Carvalho et al., 2014).

This study revealed significant improvements in 20m sprint performance, and also this improvement was found greater when applied in systemic hypoxia contrary to that in normoxia. The effects of hypoxia on sprint has so far been manifested through repeated sprint training sessions up to now, but in the study just plyometric training produced improvement in sprint. Moreover, it has been stated that the training programs involving vertical plyometric exercises do not provide a significant improvement in sprint acceleration (de Villarreal et al., 2012), but in the study this improvement was obtained by just 4 plyometric exercises and there was just one exercise (split squat jump) including horizontal acceleration.

The 8-week plyometric training in this study resulted in significant improvements in jump parameters in both training groups, especially in the hypoxia group. The jump height nearly doubled with the addition of hypoxia factor to the same training that was applied in the normoxia group. On the other hand, the normoxia group improved significantly only in the CMJ while the hypoxia group improved significantly in all the jump tests.

It is seen that both plyometric exercises and hypoxia have impacts on anaerobic performance. The plyometric training applied both under hypoxic and normoxic conditions demonstrated significant improvement in peak power and relative peak power. It is observed that peak power and min. power values are greater in hypoxia group while average power is better in the normoxia group. At altitude, it was stated the improvements in anaerobic exercise performance most probably depend on the reduced effect of drag in association with the thinner air (Hoffman, 2002). However, in the current study the improvements in anaerobic power can not result from the reduced drag effect because of the normobaric hypoxia implementation (not a real altitude), but it can be due to the further stimulation of the anaerobic metabolism (Álvarez-Herms et al., 2014). The difference in anaerobic peak power between the hypoxia and normoxia group may be due to the enhanced muscular buffer capacity and improvements in anaerobic metabolism in the hypoxia group.

It is found that the hypoxia group is better at Flex. peak power than the control group and at relative Ext. maxTorque than normoxia group at the speed of 60°/sec. Only the hypoxia group showed significant improvements in Flex. maxTorque and in Flex. peak power. In addition, at 180°/sec, relative Flex. maxTorque was significantly higher in the hypoxia group than contol group, and Flex. peak power was significantly higher again in the hypoxia group than both normoxia and control groups. Also, Flex. peak power significantly improved in just the hypoxia group. The reason for strength development resulting from hypoxic is mostly attributed to the increase of type II motor units recruitment (Manimmanakorn, Hamlin et al., 2013; Park, 2010) resulting from occurrence of preferential recruitment rather than size principle (Manimmanakorn, Manimmanakorn et al., 2013; Takarada et al., 2000). Another potential reason is the increase in growth hormone (Teramoto and Golding, 2006) in the literature. However, it is thought that the knee flexion and extension strength improvement seen in the hypoxia group in the present study may be owing to the neural developments, because neural adaptations are the main mechanism as a reason for improvements in muscular strength in the early stages of resistance training, like first 6-8 weeks; and the subsequent stages lead to increase of hypertrophy and fast fiber type conversions (Bird, Tarpenning, & Marino, 2005).

In conclusion, although the same exercise program (with the same number of repetitions and set) was applied for the same period of time in both of the training groups, the rate of improvement was found greater in hypoxia group. Moreover, unlike other combine strength training, similar improvements were obtained without requiring extra time and heavy loads. Although there was no significant difference in body composition in the study, significant improvements were observed in the strength values of hypoxia group, and the hypoxic group showed greater improvement in sprint and jump variables, suggesting that the improvement was resulting from neural development rather than hypertrophy. Also, it is known that rapid muscle actions in explosive power training lead to improvements in neural contribution of the nervous system or its synchronization of motor unit firing patterns with little contribution of hypertrophy (Bompa, 1999), and explosive force gained from the SSC puts the nervous system into practice more than the majority of other forms of training (Bağırgan, 2013). This knowledge is well known for the plyometric training effect in normoxic conditions, and it is seen in the current study that the hypoxia enhances the contribution of this neural development.

Literature has said that the hypoxic environment produces potential advantageous for the advancement of muscle performance with the improvement of hypertrophy and increments in strength and speed of explosive movements, however, improvements for normobaric hypoxia (not real altitude) still needs clarification (Feriche et al., 2017). With the result of the present study it can be concluded that normobaric hypoxia is also effective for performance improvement especially in explosive activities, most likely based on the neural contribution.

6.1. Recommendations

1. It is recommended that plyometric training should be tried with different hypoxia models like LHTL and LHTH, and it can be examined also at real high altitude because the literature supports that the anaerobic activities are more advantageous at high altitude.
2. Plyometric training in hypoxia should be studied with large sample size.
3. The effects of plyometric training in hypoxia should be studied in shorter training periods (<8 weeks) and if it provides the similar improvements also in shorter periods, it can be recommended for the preparation process of the competitions which require rapid development in a short time.
4. For future studies, to take measurements of neural activity and hypertrophy is recommended and if possible it should be measured whether muscle fiber type transformation occurred or not.
5. This training may be applied to different populations such as elite athletes. Furthermore, it can be tried on females and also at different ages to check the effects in further researches.
6. The results of this study can be tested at different altitude levels, and with different plyometric exercises. Also, it should be performed in addition to the training of a sports branch to look at the combination effects.
7. The dietary habits of participants should be tried to be controlled as much as possible.

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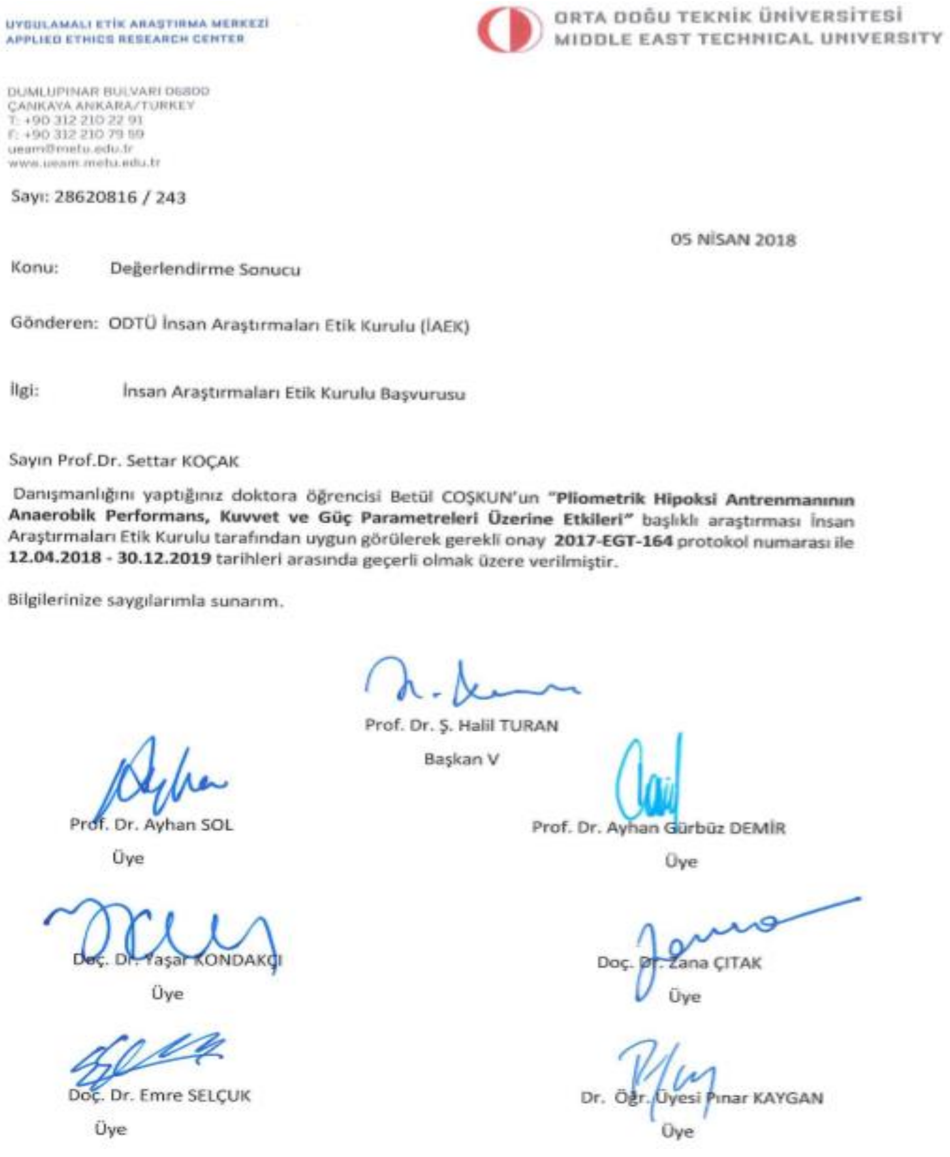
APPENDICES

APPENDIX A: APPROVAL LETTER FROM MIDDLE EAST TECHNICAL UNIVERSITY HUMAN SUBJECTS ETHICS COMMITTEE



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05 NİSAN 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Settar KOÇAK

Danışmanlığını yaptığınız doktora öğrencisi Betül COŞKUN'un **"Pliometrik Hipoksi Antrenmanının Anaerobik Performans, Kuvvet ve Güç Parametreleri Üzerine Etkileri"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2017-EGT-164** protokol numarası ile **12.04.2018 - 30.12.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Doç. Dr. Emre SELÇUK
Üye

Dr. Öğr. Üyesi Pınar KAYGAN
Üye

APPENDIX B. INFORMED CONSENT FORM

ARAŞTIRMAYA GÖNÜLLÜ KATILIM FORMU

Bu araştırma, ODTÜ Beden Eğitimi ve Spor Bölümü doktora öğrencilerinden Betül Coşkun tarafından yürütülmektedir. Bu form sizi araştırma koşulları hakkında bilgilendirmek için hazırlanmıştır.

Çalışmanın Amacı Nedir?

Araştırmanın amacı, hipokside uygulanan pliometri antrenmanının anaerobik performans, kuvvet ve güç parametreleri üzerine etkilerinin incelenmesidir.

Bize Nasıl Yardımcı Olmanızı İsteyeceğiz?

Araştırmaya katılmayı kabul ederseniz, öntestlerde elde edilen performans durumlarınıza göre, eşit bir şekilde gruplara dağılımınız sağlanacaktır. 8 hafta boyunca haftada 3 gün sıçrama egzersizlerinden oluşan bir antrenman programı uygulatılacaktır. 8 haftalık antrenman periyodu öncesi ve sonrası boy, kilo, beden kitle indeksleri ve anaerobik performans değerleri ölçülecek; kuvvet ölçümü için izokinetik bacak kuvveti ölçümleri ve reaktif kuvvet ölçümü (düşerek sıçrama testi ile), bacak gücü için ise dikey sıçrama ve squat sıçrama testleri yapılacaktır. Anaerobik performans ölçümü için bisiklet ergometresinde Wingate anaerobik güç testi yapılacaktır. Ölçümler fizyolojik ya da psikolojik herhangi bir zarar içermemektedir.

Sizden Topladığımız Bilgileri Nasıl Kullanacağız?

Araştırmaya katılımınız tamamen gönüllülük temelinde olmalıdır. Sizden kimlik belirleyici hiçbir bilgi istenmemektedir. Performans testleri sonucunda elde edilen veriler, sadece araştırmacılar tarafından değerlendirilecektir ve bilimsel yayınlarda kullanılacaktır. Sağladığınız veriler gönüllü katılım formlarında toplanan kimlik bilgileri ile eşleştirilmeyecektir.

Katılımınızla ilgili bilmeniz gerekenler:

Ölçümler fizyolojik ya da psikolojik herhangi bir zarar içermemektedir. Ancak, katılım sırasında herhangi bir nedenden ötürü kendinizi rahatsız hissederseniz testi yarıda bırakmakta serbestsiniz.

Araştırmayla ilgili daha fazla bilgi almak isterseniz:

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Beden Eğitimi ve Spor bölümü araştırma görevlisi Betül Coşkun (E-posta: bcoskun@metu.edu.tr) ile iletişim kurabilirsiniz.

Yukarıdaki bilgileri okudum ve bu çalışmaya tamamen gönüllü olarak katılıyorum.

(Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

İsim Soyad	Tarih	İmza
	---/----/-----	

APPENDIX C. CURRICULUM VITAE PERSONAL INFORMATION

PERSONAL INFORMATION

Surname, Name: Coşkun Betül

Nationality: Turkish (TC)

Date and Place of Birth: 18 April 1987, Kayseri

Marital Status: Single

email: betulcoskun_19@hotmail.com

EDUCATION

Degree	Institution	Year of Graduation
MS	Erciyes University, Department of Movement and Training Sciences	2011
BS	Erciyes University, Department of Physical Education and Sports Teaching	2009

WORKING EXPERIENCE

2011 December	Niğde Ömer Halisdemir University, School of Physical Education and Sports	Research Assistant
2011 - 2019	Middle East Technical University, Department of Physical Education and Sports	Research Assistant

FOREIGN LANGUAGES

English

PUBLICATIONS IN THE LAST 5 YEARS

Articles in Peer Reviewed International Journal

Coşkun, B., Ünlü, G., Golshaei, B., Kirazcı, S., Koçak, S., (2019).

Comparison of the static and dynamic balance between normal-hearing and hearing impaired wrestlers. *Montenegrin Journal of Sports Science and Medicine,* 8(1).

Hazır, T., Esatbeyoğlu, F., **Coşkun, B.,** Köse, M.G., Atabey, C.I. (2018). Değişik eğimlerde yürüyüş esnasında enerji harcaması: yöntemsel karşılaştırma. *Hacettepe Journal of Sport Sciences*, 29(2), 67-78.

Deliceoğlu, G., Ünlü, G., **Coşkun, B.,** Tortu, E., Kocahan, T., Koçak, M.S. (2017). The effect of ground contact time and drop height on work and power outputs for drop jump in Youth Turkish National volleyball players. *Niğde University Journal of Physical Education and Sport Sciences,* 11(3), 253-258.

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Aksoy, C., Sarıtaş, N., **Coşkun, B**. (2016). The comparison of anxiety level between male and female athletes in amateur teams. *Ovidius University Annals, Series Physical Education Sport/Science, Movement Health,* 16(2), 280-284.

Aras, D., **Coşkun, B.** (2016). The changes on the HRV after a Wingate anaerobic test in different simulated altitudes in healthy physically active adults. *Acta Medica Mediterranea,* 32, 1683-1688.

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Abakay H., Sarıtaş, N., **Coşkun, B.**, Karakuş, M. (2015). Treadmilde yürüyüş egzersizi yaptırılan serabral palsili çocukların bazı kan parametrelerine etkisi. *Erciyes Üniversitesi Sağlık Bilimleri Dergisi*, 24(3), 163-169.

Peer-Reviewed Oral Presentations

Coşkun, B., Aras, D., Akalan, C., Koçak, M. S. The effect of plyometric training in hypoxia on body composition, sprint and jump parameters. 16th International Sport Sciences Congress, 31 October - 3 November 2018, Antalya, Turkey.

Coşkun, B., Ünlü, G., Golshaei, B., Koçak, M. S., Kirazcı, S. Comparison of static and dynamic balance between normal and hearing-impaired wrestlers. 14th International Sport Sciences Congress, 1-4 November 2016, Antalya, Turkey.

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APPENDIX D. TURKISH SUMMARY / TÜRKÇE ÖZET

GİRİŞ

Yükseklik antrenmanları pek çok formda dünya çapındaki sporcular tarafından kullanılmaktadır (Lundby & Robach, 2016) ve deniz seviyesindeki performansı artırmada sporcular tarafından kullanımı giderek artmaktadır (Álvarez-Herms ve diğ., 2014; McLean ve diğ., 2014). Antrenman stresine ek olarak hipoksiye maruz kalmanın verdiği ekstra stres, egzersiz adaptasyonlarını ve performansı daha çok artırmaktadır (Morton & Cable, 2005). Nedeni ise, irtifadaki hipoksinin, fiziksel antrenmanın etkilerine benzer bir şekilde, toplam kan hacminde, hemoglobinde, kırmızı kan hücresi sayısında, mitokondriyal konsantrasyonda gelişimler ve kas enzim değişimleri gibi fizyolojik değişiklikler sağlayan bir stres faktörü olmasıdır (Fox ve diğ., 1988).

Yüksek irtifaya çıkmak genellikle bozulan dayanıklılık performansı ile ilişkilendirilir ancak irtifada kalmak, kronik adaptasyonlar sağlayarak aerobik enerji sistemiyle bağlantılı faydalı değişimler yapar ve performansı iyileştirir (Feriche ve diğ., 2017). Rekabet avantajı elde etmek için, birçok elit dayanıklılık sporcusu düzenli olarak yüksek irtifada kalır veya farklı yöntemlerle hipoksi antrenmanı yapar (Brocherie ve diğ., 2017). Ancak oksidatif olmayan metabolizmaya dayanan kısa süreli aktivitelerin de irtifa koşullarında uygulandığında hızlı faydalar sağladığı bildirilmektedir (Feriche ve diğ., 2017).

Sporcular hipoksi antrenmanı olarak, ya yüksekte yaşayıp yüksekte antrenman (Live High-Train High, LHTH) yapmayı ya da yüksekte yaşayıp alçakta antrenman (Live High-Train Low, LHTL) yapmayı tercih ediyorlardı. Ancak bu iki teknikte de fizyolojik faydalara ulaşmak için gerekli olan hipoksi dozu elde etmek kısmen uzun süreli maruz kalmalar gerektirmektedir (en az 2 hafta/günde 12 saatten fazla) (McLean ve diğ., 2014). Bu yüzden alçakta yaşayıp yüksekte antrenman (Live Low- Train High, LLTH) gibi alternatif hipoksi teknikleri önem kazanmıştır (Brocherie ve diğ., 2017; McLean ve diğ., 2014). Bu tekniğin altında yatan mantık ise normoksi koşullardaki aynı antrenmandan daha fazla iskelet kası adaptasyonu sağlama fikrinden gelmektedir (Lundby & Robach, 2016). Bu teknikte sporcular normoksi şartlarda yaşar ancak antrenmanlarını hipoksi şartlar altında yaparlar. Ayrıca hipoksiye maruz kalma süresi de genellikle daha kısadır (yaklaşık olarak haftada 2-5 kez, 3 saatten daha kısa süre) (McLean ve diğ., 2014).

Bu yöntemin deniz seviyesindeki performansı artırmadaki faydaları kısa süreli-yüksek şiddetli maksimal aralıklı egzersizler (tekrarlı sprint gibi) gibi anaerobik eforlarda kendini daha çok göstermektedir (Álvarez-Herms ve diğ., 2014; McLean ve diğ., 2014). Hipokside, aerobik ATP üretimindeki düşüş nedeniyle, enerji gereksinimi çoğunlukla, kuvvetli egzersizler sırasında aynı egzersiz şiddetini sürdürmek için anaerobik kaynaklar tarafından sağlanmaktadır (Álvarez-Herms Julià-Sánchez, Gatterer, ve diğ., 2015).

Bu model içerisindeki başlıca antrenman çeşitlerinden birisi Sürekli Hipoksi Antrenmanı (Continuous Hypoxic Training, CHT)'dır. LLTH uygulamaları daha çok anaerobik kapasite ile alakalı mekanizmalarda adaptasyon sağladığı için, CHT'de kullanılan egzersiz şiddetleri ekstra bir antrenman faydası sağlamada yetersiz kalmaktadır (McLean ve diğ., 2014).

İkinci antrenman tipi Aralıklı Hipoksi Antrenmanı (Interval / Intermittent Hypoxic Training, IHT)'dır. Bu antrenman tipiyle ilgili çalışmaların çoğu hipoksi uyaranının ekstra bir faydasının olmadığını belirtirken belli şartlarda uygulandığında daha fazla gelişmeler sağlayacağını bildiren sınırlı sayıda çalışmaya ulaşılmaktadır (McLean ve diğ., 2014) ve etkileri ile ilgili çelişkili sonuçlar vardır (Faiss, Girard, & Millet, 2013; Girard ve diğ., 2017).

Üçüncü antrenman tipi Hipokside Tekrarlı Sprint Antrenmanı (Repeated Sprint Training in Hypoxia, RSH)'dır. Çalışmalar bu tip antrenmanların daha çok tekrarlı sprint yeteneğini artırdığını bildirmektedir (Brocherie ve diğ., 2017; Girard ve diğ., 2017; McLean ve diğ., 2014).

Dördüncü antrenman tipi ise Hipokside Direnç Antrenmanı (Resistance Training in Hpoxia, RTH)'dır. Normoksi şartlardaki direnç egzersizlerinin spor alanındaki popülerliği artarken, bir yandan da hipoksi uyaranının ekstra etkileri üzerindeki ilgi artmış ve hipokside direnç egzersizleri (RTH) ortaya çıkmıştır (Girard ve diğ., 2017). Ancak bu tip antrenman ile ilgili pek az çalışma vardır ve etkileri net değildir (Girard ve diğ., 2017; McLean ve diğ., 2014).

Yapılan literatür taramasında, sistemik hipoksi yöntemlerinden LLTH antrenman modelleri arasında, sadece yukardaki 4 antrenman modelinden bahsedilmiş ancak salt bir pliometri antrenmanı ile hiç karşılaşılmamıştır.

Pliometri antrenmanlarının ise kas gücü, kuvveti ve sürati artırdığı günümüze kadar pek çok çalışma ile ispatlanmıştır. Birçok spor dalında özellikle sıçrama performansı üzerinde pozitif etkileri görülmektedir (Slimani ve diğ., 2016).

Pliometrik antrenmanların, motor ünite aktivasyonunda artış gibi spesifik nöral adaptasyonlara yol açtığı ve ağır kuvvet antrenmanlarına nazaran daha düşük kas hipertrofisine neden olduğu bildirilmektedir (Slimani ve diğ., 2016). Ayrıca, pliometri egzersizlerinin, çeşitli antrenman türleriyle kombinasyonlarını bulmak mümkündür (pliometri ve kuvvet, pliometri ve aerobik, pliometri ve esneklik, pliometri ve elektrostimülasyon, ve su içi pliometri) (de Villarreal ve diğ., 2009) fakat henüz hipoksi ile birleştirilmiş bir pliometri antrenmanına rastlanmamıştır.

Bu çalışmanın amacı, hipokside uygulanan pliometri antrenmanının etkilerini incelemek için, hipoksi ve normoksideki pliometri antrenmanının vücut kompozisyonu, sıçrama performansı, sprint zamanı, Wingate anaerobik güç testi ve izokinetik kuvvet testi sonuçları üzerindeki etkilerini karşılaştırmaktır.

Çalışmanın Önemi

Spor ve egzersiz literatüründe, daha kısa sürede daha fazla verim sağlayacak egzersiz modeli arayışları yıllardır sürmektedir. Yapılacak olan bu çalışma, deniz seviyesinde yapılan aynı egzersiz programlarından daha fazla verim elde etme konusunda ümit verici görünmekte ve uygulanması açısından literatürde ilk olma özelliği taşımaktadır. Bugüne kadar yapılan hipoksi antrenman yöntemleri arasında pek çok antrenman modeli uygulanmasına rağmen salt bir pliometri antrenmanı hipoksik şartlarda denenmemiştir. Normoksi şartlarda yapılan benzer antrenman programlarının hipoksik şartlar altında uygulandığında daha fazla fizyolojik ve kassal adaptasyonlar sağlayarak, daha yüksek performans verimi sergileme fikrinden dolayı, mevcut çalışmada bu adaptasyon ve performans etkilerinin pliometrik egzersizler için de geçerli olup olmayacağının araştırılması amaçlandı.

Ayrıca, kas kuvveti veya güç gelişimi hipoksik koşullar altında çok fazla değerlendirilmediğinden, aralıklı veya uzun süreli hipoksiye maruz kalmanın güç antrenmanı üzerine etkilerini bulmak amacıyla, bilimsel çalışmalar arasında kontrollü ve güce yönelik direnç antrenmanı araştırmalarına ihtiyaç vardır. Yükseltiye çıkmanın hız ve güç gelişimine neden olduğu, ancak normobarik hipoksideki hipoksi kaynaklı gelişmelerden sorumlu olan mekanizmaların henüz net olmadığı ve araştırılması gerektiği belirtilmektedir (Feriche ve diğ., 2017).

Çalışma sonucunda hipokside yapılan pliometrik egzersizin normokside yapılandan daha yüksek oranda performansı artırması halinde literatüre yeni bir hipoksi egzersiz modeli kazandırılmış olacak ve ayrıca ilerleyen çalışmalar için, kuvvet, güç ve anerobik performans gerektiren pek çok spor dalında pliometri egzersizlerinin hipoksik şartlar altında denenmesi önerilecektir.

Araştırma Sorusu

Pliometrik hipoksi ve normoksi antrenmanının, vücut kompozisyonu, sıçrama performansı değişkenleri, sprint testi, Wingate anaerobik güç testi ve izokinetik kuvvet testi üzerine etkileri arasındaki farklar nelerdir?

Alt Sorular

1. Hipoksi ve normoksideki pliometrik antrenmanın vücut kompozisyonu üzerinde anlamlı bir etkisi var mıdır?
2. Hipoksi ve normoksideki pliometrik antrenmanın sıçrama testlerinin parametreleri üzerinde anlamlı bir etkisi var mıdır?
3. Hipoksi ve normoksideki pliometrik antrenmanın sprint testi üzerinde anlamlı bir etkisi var mıdır?
4. Hipoksi ve normoksideki pliometrik antrenmanın Wingate anaerobik güç testi değişkenleri üzerinde anlamlı bir etkisi var mıdır?
5. Hipoksi ve normoksideki pliometrik antrenmanın izokinetik kuvvet testlerinin değişkenleri üzerinde anlamlı bir etkisi var mıdır?

Çalışmanın Amacı

Bu çalışmanın amacı, hipoksi ve normoksideki pliometrik antrenmanın vücut kompozisyonu, sıçrama performansı, sprint zamanı, Wingate anaerobik güç testi ve izokinetik kuvvet testi sonuçları üzerindeki etkilerini karşılaştırmaktır.

Çalışmanın Sınırlılıkları

1. Bu çalışma, Ankara Üniversitesi Spor Bilimleri Fakültesinde öğrenim gören, okul müfredatı dışında haftada en az 3 gün olmak üzere düzenli olarak fiziksel aktiviteye katılmayan erkek öğrencilerle sınırlandırılmıştır.
2. Sınırlı sayıda katılımcı yer almıştır.
3. Katılımcıların günlük aktiviteleri kontrol edilememiş ve çalışma süreci boyunca, bu çalışmadaki antrenman dışında herhangi bir pliometrik ve kuvvet antrenmanına katılmadıkları varsayılmıştır.
4. Katılımcıların, antrenmanlara yorgun vaziyette gelmedikleri ve testlerde en iyi performanslarını sergiledikleri varsayılmıştır.

YÖNTEM

Araştırma Deseni

Bu çalışma, deneysel araştırma tasarımlarından biri olan (Pretest-Posttest Control Group Design) Öntest-Sontest Kontrol Gruplu Dizayn olarak tasarlanmıştır. Antrenman sürecinin öncesi ve sonrasında bütün gruplara performans testleri uygulanmıştır.

Örneklem

Bu araştırmanın örneklemi, Ankara Üniversitesi Spor Bilimleri Fakültesinde öğrenim gören, okul müfredatı dışında haftada en az 3 gün düzenli olarak fiziksel aktiviteye katılmayan 23 gönüllü erkek öğrenciden (Yaş = 20.39 ± 2.02; Boy = 177±7.5) oluşmaktadır. Katılımcılar, son 6 ay içerisinde direnç egzersizi ve pliometrik egzersizler yapmayan bireylerden seçilmiştir (Vissing ve diğ., 2008). Son 2 yıl içerisinde alt ekstremite ameliyatı geçirmiş ya da iyileşmemiş bir kas-iskelet rahatsızlığı olanlar çalışmaya dahil edilmemiştir (Chimera ve diğ., 2004; MacDonald ve diğ., 2012). Ayrıca, performans artırıcı herhangi bir ilaç, anabolik steroid ya da hormon kullananlar çalışmaya dahil edilmemiştir (de Villarreal ve diğ., 2008; Ramírez-Campillo ve diğ., 2014).

Katılımcılar, öntest performans sonuçları dikkate alınarak PTH (hipokside pliometri antrenmanı grubu) (n = 8), PTN (normokside pliometri antrenmanı grubu) (n = 7) ve Kontrol grubu (n = 8) olmak üzere 3 gruba ayrılmıştır. Araştırmacının, hangi değişkenlerin problem ya da önyargı oluşturabileceğini belirlemesi ve bunların etkilerini en aza indirmeye çalışması gerektiğinden (Fraenkel ve diğ., 2012), grupların oluşturulması bireylerin öntest performans sonuçlarına dayanarak yapılmıştır. Öntest performans değerleri en yüksekten en düşüğe doğru sıralandı ve üç bölüme ayrıldı (düşük-orta-yüksek puan olarak). Bu üç puan bölümünden birer kişi, her grupta 10 kişi tamamlanıncaya kadar Hipoksi (PTH), Normoksi (PTN) ve Kontrol (Control) gruplarına rastlantısal olarak atanmıştır. Çalışmaya 30 öğrenci ile başlandığı için her gruba 10'ar kişi atanmıştır. Ancak üst üste devamsızlık yapan ve yapmamaları gerektiği uyarısına rağmen çalışmadaki antrenmanın yanısıra ekstra kuvvet antrenmanı yapanlar analizlere dahil edilmemiştir. 2 öğrenci ise atletizm derslerinde meydana gelen alt ekstremite yaralanması nedeniyle antrenmanlara devam edememiştir. 3 günden fazla antrenmana katılmayan bireyler çalışmadan çıkarılmıştır. Üç grup arasında öntest değerlerinde anlamlı bir fark bulunmamıştır.

Çalışmaya başlamadan önce Orta Doğu Teknik Üniversitesi Uygulamalı Etik Araştırma Merkezi'nden gerekli izinler alınmıştır. Çalışma hakkında bilgi verildikten sonra tüm katılımcılardan yazılı onay alınmıştır.

Deneysel Prosedür

PTH grubu, pliometri antrenmanını, portatif hipoksik jeneratöre (Everest Summit II, Hypoxia, NY, ABD) bağlı bir yüz maskesi ile normobarik hipoksik ortam sağlanarak (yaklaşık 3.536 m) 8 hafta boyunca haftada 3 gün (Pazartesi, Çarşamba, Cuma) uygulanmıştır. PTN grubu ise aynı antrenman programını normoksi ortamda maske kullanmaksızın uygulamıştır. Egzersizler esnasında PTH grubunun ortalama oksijen saturasyonu %82.8 ve %84.7 arasında iken, PTN grubunun oksijen saturasyonu %95.3 ve %96 arasında değişiklik göstermiştir. Her iki gruba da aynı zamanda ders proğramlarındaki fiziksel aktivitelerine devam etmeleri söylenmiş, üçüncü grup olan Kontrol grubuna ise herhangi bir egzersiz protokolüne maruz kalmadan sadece ders proğramlarındaki fiziksel aktivitelerine devam etmeleri ve pliometrik model egzersizlerden kaçınmaları söylenmiştir. Egzersizler başlamadan 2-3 gün önce öntestler (Vissing ve diğ., 2008) ve bittikten 5-6 gün sonra sontestler yapılmıştır (Álvarez-Herms ve diğ., 2014).

Egzersiz Protokolü

Sıçrama egzersizlerinin öncesinde 10 dk koşu ve ardından 5 dk esnetme yapılmıştır. Hipoksi grubundaki katılımcılara 10 dklık koşunun hemen sonrasında hipoksi maskesi takılmıştır. Hipoksi grubu, esneme egzersizlerini, sıçrama egzersizlerini ve soğuma egzersizlerini barındıran 25- 35/40 dk lık süre boyunca hipoksiye maruz kalmıştır. Egzersizlere başlamadan önce ve her bir egzersizin bitiminde oksijen saturasyonları ve kalp atım hızı ölçülerek hipoksiye maruz kalıp kalmadıkları kontrol edilmiştir. Tüm katılımcılardan egzersizleri maksimum eforla yapmaları istenmiştir. Pliometrik egzersizlerin bitiminde 5 dk soğuma yaptırılmıştır. Isınma dahil toplam antrenman süresi 35-50 dk arasında sürmüştür.

Pliometrik antrenmanda uygun performans için dinlenme oranı 1:5'ten 1:10'a kadar verilmelidir (Chu & Myer, 2013). Hipokside ise, kuvvet antrenmanı için 1:2 ve 1:3 önerilirken, tekrarlı sprint yeteneği testleri için genellikle daha uzun süreli dinlenme aralıkları (1: 5+) kullanılmaktadır. Ancak hipokside hem kuvvet hem de tekrarlı sprint antrenmanlarında performans gelişimi için çoğunlukla kısa ve tam olmayan dinlenmeler önerilmektedir (Scott ve diğ., 2016). Bu yüzden bu çalışmada dinlenme oranı 15-20 saniyeden kısa süren setler için 1:5 ve 20 saniyeden uzun süren setler için 1:2 ve 1:3 verilmiştir.

Antrenman programı, Vissing ve diğ. (2008)'nin uyguladığı programa dayanarak tasarlanmış, ancak egzersizlerin hipoksik jeneratör kullanım eşliğinde yapılabilmesi için bazı farklılıklar uyarlanmıştır. Bu farklılıklardan birisi seçilen egzersiz tipidir. Vissing ve diğ. (2008)'nin çalışmasında CMJ (aktif sıçrama) ve DJ (düşerek sıçrama) ile birlikte engel sıçrama kullanılırken, bu çalışmada ilk 4 hafta CMJ (aktif sıçrama) ve DJ (düşerek sıçrama) ile SJ (squat sıçrama) ve Split SJ (split squat sıçrama) kullanılmıştır. Son 4 haftada ise split SJ çıkarılıp, diğer egzersizler için ekstra bir set daha eklenmiştir. Ayrıca literatür antrenman kazanımlarını artırmak için SJ, CMJ ve DJ egzersizlerinin kombinasyonunu, bu egzersizlerin yalnız uygulanmasından daha çok önermektedir (de Villarreal ve diğ., 2009).

Egzersizlerde ekstra ağırlıklar kullanmak, pliometri antrenmanındaki performans kazanımlarını anlamlı derecede artırmadığı için (de Villarreal ve diğ., 2009), bu çalışmada ekstra ağırlıklara gerek duyulmamış ve ekstra antrenman uyaranı olarak sadece hipoksi kullanılmıştır.

Antrenman sayısı 24 seanstan oluşmaktadır ve literatürde önerildiği gibi ilk haftaki antrenman 60 sıçrama ile başlamıştır (antrenman sayısı >20 ve antrenman başına sıçrama >50) (de Villarreal ve diğ., 2009). Set ve tekrar sayıları ise antrenman periyodu boyunca aşamalı olarak artırılmıştır. Antrenman programı aşağıdaki tabloda verilmiştir.

Haftalar	**1. hafta**	**2. hafta**	**3. hafta**	**4. hafta**	**5. hafta**	**6. hafta**	**7. hafta**	**8. hafta**
Antrenman	1.2.3.	4.5.6.	7.8.9.	10.11.12.	13.14.15.	16.17.18.	19.20.21.	22.23.24.
Egzersizler								
DJ	3 x 5	3 x 7	3 x 9	3 x 5	4 x 9	4 x 11	4 x 13	4 x 9
SSJ	3 x 5	3 x 7	3 x 9	3 x 5	-	-	-	-
CMJ	3 x 5	3 x 7	3 x 9	3 x 5	4 x 9	4 x 11	4 x 13	4 x 9
SJ	3 x 5	3 x 7	3 x 9	3 x 5	4 x 9	4 x 11	4 x 13	4 x 9
Antrenmanda	**60**	**84**	**108**	**60**	**108**	**132**	**156**	**108**
Haftada	3x60	3x84	3x108	3x60	3x108	3x132	3x156	3x108
Toplam	**180**	**252**	**324**	**180**	**324**	**396**	**468**	**324**

DJ: Düşerek sıçrama, **SSJ:** Split squat sıçrama, **CMJ:** Aktif sıçrama, **SJ:** Squat sıçrama

Veri Toplama Prosedürü

8 haftalık antrenman periyodu öncesi ve sonrası her üç grubun boy, kilo ölçümleri ve Biyoelektrik İmpedans Analizleri yapılmış, CMJ ve SJ testleri uygulanmıştır. Anaerobik performans değerleri Wingate anaerobik güç testi ile ölçülmüştür. Eksantrik ve konsantrik kuvvet bileşimi reaktif kuvveti sağlamakta ve alt ekstremite reaktif kuvvet performansı çoğunlukla DJ yüksekliği kullanılarak test edilmektedir (Gamble, 2009). Bu yüzden öntest ve son testlerde DJ testi de uygulanmıştır. Kuvvet ölçümü için izokinetik bacak kuvveti ölçümleri yapılmış, yatay düzlemde patlayıcı güç kazanımlarını değerlendirmek için ise 20 m sprint testi kullanılmıştır.

20 metre sprint testi sıçrama testleri ile aynı gün yapılırken, izokinetik kuvvet ölçümü, Wingate testi ve sıçrama testleri ise üç farklı günde uygulanmıştır.

Katılımcılara test süreci boyunca yeme ve uyku alışkanlıklarını bozmamaları ve şiddetli antrenmandan kaçınmaları söylenmiştir (Chen ve diğ., 2013).

Veri Toplama Araçları ve Protokoller

Boy Uzunluğu

Boy uzunluğu dik durur vaziyette ve çıplak ayakla ölçülmüştür. Katılımcı topuklarını birleştirip, başını dik tutmuştur. Derin bir nefes alıp, nefesini tuttuğunda kişi karşıya bakarken başının üzerindeki en yüksek nokta 1 mm hassasiyetle ölçülmüştür (ACSM, 2010).

Vücut Ağırlığı ve Biyoelektrik İmpedans Analizi

Kilo ve vücut kompozisyonu değerleri ‘PlusAvis 333 analyzer’ (Jawon Medical, SOUTH KOREA) ile ölçülmüştür. Katılımcılara en az 4 saat önce yeme ve içmeyi, en az 12 saat önce ise fiziksel aktiviteyi bırakmaları söylenmiştir. Ayrıca testten 30 dk öncesine kadar mesanelerini boşaltmaları ve test esnasında üzerlerinde metal eşya bulunmaması gerektiği hatırlatılmıştır (ACSM, 2010).

Wingate Anaerobik Güç Testi

Test, ‘Monark Peak Bike’ marka ve ‘Ergomedic 894 E’ model (Monark, Sweden) bisiklet ergometresi kullanılarak yapılmıştır. Katılımcılar testten önce 60-80 rpm hızda 4 dakikalık ısınma uygulamışlardır. Isınmanın 1.30 ve 2.30’uncu dakikalarında 4 saniyelik 2 sprint yapmışlar ve ısınmanın ardından 4 dk dinlenmişlerdir (Aras ve Coskun, 2016). Test yükü vücut ağırlığının %7.5’i olarak seçilmiş ve katılımcılar test boyunca maksimal güç uygulamaları için sözel olarak teşvik edilmiştir.

İzokinetik Kuvvet Testi

İzokinetik diz kuvveti ölçümleri Isomed 2000 marka izokinetik dinamometreyle ölçülmüştür. Katılımcıların izokinetik sağ ve sol bacak quadriceps, hamstring ve quadriceps/hamstring kuvvet oranları 60°/sn ve 180°/sn açısal hızlarda 5 tekrar ile ölçülmüştür (Özkan & Kin-işler, 2010; Ölçücü ve diğ., 2011). Maksimum Tork değerlendirmek için genellikle ilk 2-6 arasında kasılma tekrar sayısının uygun olduğu düşünülmekte ve Perrin (1993) 3-4 tekrar önermektedir.

İzokinetik ölçüm öncesi katılımcılar ısınma amacıyla koşu bandında 5 dk boyunca 6 km hızda koşu ve ardından 5 dk esneme ve germe egzersizleri yapmışlardır. Daha sonra test izokinetik dinamometrede oturma pozisyonunda gerçekleştirilmiş, katılımcılar karın ve femurun orta bölgesinden bant yardımıyla koltuğa sabitlenmiş, kollardan güç almamaları için kollar göğüste çapraz vaziyette tutulmuş (Perrin, 1993; Wilkerson ve diğ., 2004) ve katılımcıların fiziki yapılarına uygun bir şekilde dinamometrenin ayarları yapılmıştır.

Perrin (1993) tarafından önerildiği gibi, her test protokolü, hem submaksimal hem de maksimal kasılmadan oluşan bir ısınma ile başlamış ve bu ısınma her test hızı için gerçekleştirilmiştir. Isınma amaçlı her bir açısal hızda 3 submaksimal kasılmayı takiben 2 maksimal kasılma yaptırılmıştır (Özkan & Kin-işler; Perrin, 1993). 4 maksimum tekrarlık bir test için 30 ile 1 dakikaya kadar dinlenme süresi önerilmekte; 25-30 tekrarlı dayanıklılık testi için ise en az 1 dakika veya daha uzun dinlenme aralığı önerilmektedir (Perrin, 1993). Bu yüzden ısınma denemelerinin ardından 30 saniye pasif dinlenme verilmiş ve esas ölçümlere geçilmiştir. Sporcular, her bir seviye için (60°/sn ve 180°/sn) 5 maksimal kasılma yapmıştır. Test uygulamaları yavaş hızdaki ölçümlerden başlamıştır (Perrin, 1993). Sağ ve sol bacak ölçümleri arasında 2 dk dinlenme verilmiş, test süresince sporcular sözel olarak teşvik edilmiştir.

20 m Sprint Testi

20 metrelik mesafesinin başlangıç ve bitişine yerleştirilen fotoseller (Newtest 100 (Finland)) arasında yarı hızda 2 deneme alınmıştır. Ardından 3 ana deneme hakkı verilmiş ve en iyi olan performans kaydedilmiştir. Denemeler arası 3 dk dinlenme verilmiştir (de Villarreal et al., 2008).

CMJ (Aktif sıçrama) Testi

Sıçrama testleri öncesinde katılımcılar 4 dakikalık yavaş koşu, 3 dk esnetme ve sıçrama denemelerinden oluşan standart bir ısınma uygulamışlardır (Young ve diğ., 1995). Bütün sıçrama testleri sıçrama matı üzerinde gerçekleştirilmiştir (Smartspeed Lite sistemi ve Smart jump mat).

CMJ testinde, katılımcılar ayakta durma pozisyonundan hızlı bir şekilde aşağı çömelme hareketine geçer ve hemen ardından maksimum bir eforla dikey sıçrama gerçekleştirir, ve ardından dik bir pozisyonda yere inişi takiben dizlerini bükerler. Katılımcılardan maksimum yükseklik için sıçrama yapmaları istenmiştir. Kolların sıçrama performansına katkısını azaltmak için sıçrama anında ellerin belde olması söylenmiştir (Özbar ve diğ., 2014; Spurrs ve diğ., 2003). Sıçramada aşağı doğru iniş hareketi sırasında dizin bükülme açısı ile ilgili herhangi bir kısıtlama getirilmemiştir (Spurrs ve diğ., 2003; Ramirez-Campillo ve diğ., 2013). 3 deneme kaydedilmiş ve en iyi olan değer analizler için kullanılmıştır (Cherif ve diğ., 2012; de Villarreal ve diğ., 2008; Ozbar ve diğ., 2014; Ramírez-Campillo ve diğ., 2013). Denemeler arası 15 saniye dinlenme verilmiştir (Ramirez-Campillo ve diğ., 2013).

SJ (Squat Sıçrama) Testi

Katılımcı dizler yaklaşık 90° bükük vaziyetteyken 3 saniye bekledikten sonra, eller belde, maksimum eforla dikey sıçrama yapmıştır. Havada iken bacakları dümdüz tutması, dik pozisyonda inişi takiben ise dizlerini bükmesi söylenmiştir (Ramirez-Campillo ve diğ., 2013; Chelly ve diğ., 2010). 3 deneme alınmış ve en iyi olan derece analizlerde kullanılmıştır. Denemeler arası 15 saniye dinlenme verilmiştir (Ramirez-Campillo ve diğ., 2013).

Verilerin Analizi

Tüm değişkenler için tanımlayıcı istatistik uygulanmış, ortalama ve standart sapma olarak sunulmuştur. Üç grup arasındaki farklar için Kruskal-Wallis H-testi; hangi ikili gruplar arasında fark olduğunu belirlemek için Mann-Whitney U-testi uygulanmıştır. Ayrıca Tip I hata oranının artışını önlemek için Bonferroni düzeltmesi yapılmıştır (ikili gruplar arasındaki farklar için, .05 olan p değerinin karşılaştırma sayısına bölünmesi ile yeni p değeri belirlenmiştir). Öntest ve son-test sonuçlarını karşılaştırmak için Wilcoxon signed-rank test kullanılmıştır. Alfa değeri .05 olarak belirlenmiştir. Tüm analizler Sosyal Bilimler için İstatistik Paketi versiyon 22 kullanılarak yapılmıştır.

BULGULAR

Biyoelektrik impedans analizinden elde edilen Vücut ağırlığı (kg), Vücut kütle indeksi (kg/m^2), Vücut yağ yüzdesi (%), Vücut yağ ağırlığı (kg) ve Yağsız vücut ağırlığı (kg) vücut kompozisyonu parametrelerinin hiçbirinde gruplar arası (Tablo 4.3) ve grup içi (öntest-sontest) karşılaştırmalarda (Tablo 4.4, Tablo 4.5, Tablo 4.6) anlamlı farklılık bulunmamıştır, $p > .05$. Ancak sadece PTH grubunda vücut yağ kütlesinde %10.14 oranında ve vücut yağ yüzdesinde %8.17 oranında istatistiksel olarak anlamlı olmayan bir azalma görülmüştür, $p > .05$ (Tablo 4.1).

20m sprint değeri gruplar arası anlamlı farklılık göstermezken (Tablo 4.9), $p > .05$; her iki pliometri antrenman grubunda öntest ve sontest arasında anlamlı derecede azalma göstermiştir, $p < .05$. PTH grubunda bu azalış %3.42 oranında ($p = .01$), (Table 4.10), PTN grubunda ise %2.58 ($p = .03$), (Table 4.11) oranındadır.

8 haftalık antrenman sonrası sıçrama değerlerinde üç grup arasında anlamlı fark görülmezken, $p > .05$, (Tablo 4.9); grup içi karşılaştırmalarda sadece PTH (Tablo 4.10) ve PTN (Tablo 4.11) gruplarında anlamlı farklılıklar bulunmuştur, $p < .05$. PTH grubunda CMJ değeri (aktif sıçrama) 5.59 cm'lik bir artış ile %14.80 oranında ($p = .01$) anlamlı gelişim göstermiştir. PTN grubunda ise bu artış, 3.19 cm ile %8.55 oranındadır ($p = .02$). SJ (squat sıçrama) performanslarında ise, PTH grubu 5.69 cm'lik bir artış ile %16.06 ($p = .01$) anlamlı gelişim göstermiştir. PTN grubunda ise bu artış 3.17 cm ile %8.83 ($p = .06$) oranında istatistiksel olarak anlamlı olmayan bir gelişimdir.

DJ (drop jump) sıçrama yüksekliğinde ise, PTH grubunda 5.24 cm'lik bir artış ile %15.97 ($p = .01$) anlamlı gelişim bulunurken, PTN grubu 2.73cm ile %7.89 ($p = .09$) anlamlı olmayan bir gelişim göstermiştir. DJ ground contact time (yerle temas süresi) değeri, PTH grubunda 11.87 milisaniye ile %5.36 ($p = .04$) anlamlı artış gösterirken, PTN grubunda 4 milisaniye ile %1.76 ($p = .74$) anlamlı olmayan düşüş göstermiştir. RSI (reaktif kuvvet indeksi) değeri PTH grubunda 0.15 artış ile %10 ($p = .04$) anlamlı gelişim göstermiştir. PTN grubu 0.15 artış ile %9.38 ($p = .40$) anlamlı olmayan gelişim göstermiştir.

Wingate testi sonuçlarında gruplar arası anlamlı farklılık görülmezken, $p > .05$, (Tablo 4.15); her iki antrenman grubu PTH (Tablo 4.16) ve PTN'de (Tablo 4.17) grup içi anlamlı değişimler görülmüştür, $p \leq .05$. Peak power (maksimum güç) değerinde PTH grubu 60.53 W (7.72%) ($p = .02$) oranında artış gösterirken, PTN grubunda bu artış 46.14 W (6.09%) ($p = .\ 03$) oranındadır. Relative peak power (rölatif maksimum güç) artışı ise PTH grubunda 0.89 W/kg (7.89%) ($p = .05$), PTN grubunda 0.81 W/kg (7.05%) ($p = .02$) oranındadır. Average power (ortalama güç) her üç grupta da anlamlı değişim göstermezken, $p > .05$, Relative average power (rölatif ortalama güç) ise PTH grubunda anlamlı olmayan 0.36 W/kg (4.41%) ($p = .07$) artış gösterirken, PTN grubu 0.79W/kg (10.06%) ($p = .02$) anlamlı artış sağlamıştır.

İzokinetik kuvvet testi sonuçları ise hem gruplar arası hem grup içi anlamlı farklılıklar göstermiştir. 60°/sn açısal hızda alınan ölçümlere göre, Flex. peak power (fleksiyon maksimum güç) değerinde sağ bacakta PTH (103.25±14.24) ve Kontrol (82.38±15.83) grubu arasında anlamlı farklılık ($p = .01$) bulunmuştur (Tablo 4.19; 4.23). PTH grubunun Flex. peak power değeri Kontrol grubununkinden anlamlı derecede daha yüksektir, $p < .017$. Sol bacakta ise, Ext.maxTorque/weight (ekstansiyon maksimum Tork/kilo) değeri PTH (3.02±.27) ve PTN (2.22±.80) grupları arasında anlamlı farklılık ($p = .01$) göstermiştir (Tablo 4.19; 4.22). PTH grubunda bu değer PTN grubundakine nazaran anlamlı derecede daha yüksektir, $p < .017$.

Öntest ve sontest karşılaştırmasına göre ise, sağ bacakta Flex.maxTorque (fleksiyon maksimum Tork) değeri sadece PTH grubunda %15.69 oranında anlamlı artış göstermiştir ($p = .05$), $p \leq .05$, (Tablo 4.19 ve 4.25). Bu değer, PTN grubunda %11.93 oranında anlamlı olmayan artış ($p = .13$) (Tablo 4.19 ve 4.26), Kontrol grubunda % 1.52 oranında anlamlı olmayan düşüş ($p = .78$) (Tablo 4.19 ve 4.27) göstermiştir, $p > .\ 05$. Ayrıca, yine sadece PTH grubunda sağ bacakta Flex. peak power değeri (%18) anlamlı artış ($p = .05$), $p \leq .05$, (Tablo 4.19 ve 4.25) gösterirken; PTN grubu (%13.35) anlamlı olmayan bir artış göstermiştir ($p = .13$), $p > .05$, (Tablo 4.19 ve 4.26). Kontrol grubu ise sağ bacakta Ext.maxTorque

(Ekstansiyon Maksimum Tork) (*p* = .01) değerinde ve sol bacakta Ext.maxTorque (*p* = .01), Ext.maxTorque/weight (*p* = .02) ve Ext.Peak Power (Ekstansiyon Maksimum Güç) (*p* = .05) değerlerinde anlamlı düşüş göstermiştir, *p* ≤ .05, (Tablo 4.19 ve 4.27).

180°/sn açısal hızdaki ölçümlere gelince, sağ bacak ölçümlerinde PTH ve Kontrol grubu arasında Flex.maxTork/weight (fleksiyon maksimum tork/kilo) değerinde anlamlı farklılık gözlenmiştir, (*p* = .01), *p* < . 017, (Tablo 4.32). PTH grubun Flex. maxTork/weight (1.72±.24) değeri Kontrol grubun (1.41±.20) değerinden anlamlı derecede yüksek bulunmuştur (Tablo 4.28 ve 4.32). Sol bacak ölçümünde ise Flex. peak power değeri PTH grubunda (196.25±42.33), hem PTN grubun (155.57±16.04), (*p* = .01), *p* < .017, (Tablo 4.28 ve 4.31) hem de Kontrol grubun (156.50±15.86), (*p* = .01), *p* < .017, (Tablo 4.28 ve 4.32) değerinden anlamlı derecede yüksek bulunmuştur.

Öntest ve sontest karşılaştırmasında ise, sağ bacak ölçümünde Flex. peak power değerinde PTN grubu anlamlı olmayan artış (%5.57), (*p* = .50), *p* > .05, (Tablo 4.28 ve 4.35) gösterirken; sadece PTH grubu anlamlı artış (%12.30), (*p* = .04), *p* < .05, (Tablo 4.28 ve 4.34) göstermiştir. Ayrıca Kontrol grubu sağ bacakta Flex.maxTorque (*p* = .05), Ext.maxTorque (*p* = .04), Flex. peak power (*p* = .04) ve Ext. peak power (*p* = .02) değerlerinde; sol bacakta ise Flex.maxTorque (*p* = .02), Flex. peak power (*p* = .02) ve Ext. peak power (*p* = .03) değerlerinde anlamlı düşüş göstermiştir, *p* ≤ .05, (Tablo 4.28 ve 4.36).

TARTIŞMA VE SONUÇ

Bu çalışmada, 8 haftalık normobarik hipokside uygulanan pliometri antrenmanı vücut kompozisyonunda anlamlı bir değişim sağlamazken, sıçrama ve sprint değerlerinde normokside uygulanan pliometri antrenmanına göre daha yüksek oranda gelişim göstermiştir.

Çalışma, normokside ugulanan çalışmalar içerisinde, süre ve egzersiz çeşitliliği olarak kendisine benzeyen çalışmalarla aynı doğrultuda sonuç vermiş ve vücut kompozisyonunda anlamlı farklılık göstermemiştir. Ancak 12 hafta gibi daha uzun süreli pliometri antrenmanlarında (Sinikumar ve diğ., 2017) ya da yine uzun süreli pliometri+kuvvet antrenmanlarında (Carvalho ve diğ., 2014) vücut kompozisyonunda gelişmeler tespit edilmiştir. Ancak, bu çalışmada 8 haftalık antrenman periyodu sonunda sadece hipoksi grubunda vücut ağırlığı, vücut yağ yüzdesi, vücut yağ ağırlığı değerlerinde istatistiksel olarak anlamlı olmayan düşüşe yatkınlık ve yağsız vücut ağırlığında istatistiksel olarak anlamlı olmayan yükselişe yatkınlık bulunmuştur. Sadece PTH grubunda görülen anlamlı olmayan bu farkın hipoksiden ve hipoksi nedenli protein sentezinden kaynaklı olabileceği düşünülmektedir. Çünkü literatür, normobarik hipoksideki kuvvet antrenmanının protein sentezinde ve yağsız vücut kütlesinde anlamlı artışlara yol açtığını desteklemektedir (Chycki ve diğ., 2016).

Bu çalışma 20 m sprint performansında anlamlı gelişim ortaya çıkarmıştır ve bu gelişmenin hipoksi grubunda daha fazla oluşu ise hipoksinin nöral adaptasyon üzerindeki etkisinin daha fazla olduğunu düşündürmektedir. Çünkü antrenmansız bireylerde güç ağırlıklı kuvvet antrenmanlarının ilk haftalarında elde edilen gelişiminin çoğu nöral adaptasyonla açıklanmaktadır (de Villarreal ve diğ., 2012). Ayrıca, hipokside uygulanan 7 haftalık ağır direnç antrenmanının (ilk 4 hafta 3100m., son 3 hafta 3400m) antrenmanlı erkekler üzerinde etkilerini araştıran farklı bir çalışmada, gruplar arası ve grup içi karşılaştırmada 20m sprint değerinde anlamlı değişim meydana gelmemiştir (Inness ve diğ., 2016). Bu çalışmada ise hipoksinin, pliometri antrenmanı ile birlikte uygulanınca beklenen nöral adaptasyonun sağlandığı düşünülmektedir. Öte yandan, şimdiye kadar hipoksinin sprint üzerine etkisi daha çok tekrarlı sprint antrenmanları ile araştırılmıştır. Örneğin, 12 seanslık tekrarlı sprint antrenmanı sonrası, Galvin ve diğerleri (2013), erkek sporcularda 5, 10, 20m sprint performansında normoksiye kıyasla hipoksi grubunda (13% FiO2) anlamlı bir gelişim bulamamıştır. Bunun aksine, kadın sporcular üzerinde yapılan 4 haftalık hipokside tekrarlı sprint antrenmanın etkilerinin araştırıldığı çalışmada, tekrarlı sprint yeteneğinde normoksi grubuna kıyasla hipoksi grubunda daha büyük anlamlı gelişmeler bulunmuştur (Kasai ve diğ., 2015). Başka bir çalışmada hipokside tekrarlı sprint antrenmanı antrenmanlı erkek ragbi oyuncularında tekrarlı sprint yeteneğini artırmıştır (Hamlin ve diğ., 2017). Brocherie ve diğerleri (2015)' nin çalışmasında, pliometri egzersizlerini de içeren 5 haftalık tekrarlı sprint antrenmanı antrenmanlı sporcular üzerinde, hipokside (2900m) uygulanmış ve 40m sprint testinde (her bir 10m' lik bölüm için) mevcut çalışmada olduğu gibi gruplar arası anlamlı farklılık olmamakla birlikte hipoksi grubu normoksi grubuna nazaran daha yüksek gelişim göstermiştir. Ayrıca dikey düzlemde uygulanan pliometri egzersizleri içeren antrenman programlarının sprint ivmesinde anlamlı gelişim sağlamadığı bildirilmektedir (de Villarreal ve diğ., 2012), ancak bu çalışmada ortaya çıkan gelişim sadece 4 çeşit pliometri egzersizi ile elde edilmiş ve bunlar içerisinde yalnızca bir egzersiz yatay ivmelenme içermektedir.

Bu çalışmadaki 8 haftalık pliometri antrenmanı, özellikle hipoksi grubu olmak üzere her iki antrenman grubunda sıçrama parametrelerinde anlamlı artışlarla sonuçlanmıştır. Pliometri antrenmanlarının, antrenmanlarla birlikte artan kas gücü ve koordinasyondan kaynaklı olarak dikey sıçrama yüksekliğinde %4.7 ile %15 arasında artış sağlayabildiği bildirilmektedir (de Villarreal ve diğ., 2009). Bu çalışmada ise hem normoksi grubunda (%8.55) hem hipoksi grubundaki (%14.80) meydana gelen anlamlı gelişim yukarda verilen yüzdelik oranlara bakıldığında yüksek sınırlardadır. Her iki gruba da aynı egzersiz programı (aynı set ve tekrar sayısı ile) aynı süre ile uygulanmasına rağmen gelişim oranı oldukça farklıdır. Bu çalışmada, Adams ve diğ., (1992) ve Fatouros ve diğ.,' lerinin (2000) çalışmalarında olduğu gibi kombin antrenman etkisi (ağırlık antrenmanı+pliometri) daha büyük bulunmuştur. Ancak çalışmada bulunan bu etki, kombin edilen antrenman türüne ekstra zaman harcanmadan ve antrenmanda ağır yükler altına girilmeden elde edilmiştir. Çünkü bu çalışmada, hipoksi grubu yalnızca ekstra bir maske takarak aynı antrenmanı uygulamıştır.

Sıçrama performansı üzerine genel olarak bakacak olursak, çalışmada normoksi grubu sadece dikey sıçramada anlamlı gelişim gösterirken, hipoksi grubu bütün sıçrama testlerinde anlamlı gelişim sağlamıştır. Başka bir çalışmada, pliometrik egzersizlerle birleştirilmiş 6 haftalık kuvvet antrenmanı, squat sıçramada anlamlı bir gelişim sağlamazken CMJ sıçrama yüksekliğinde anlamlı gelişim sağlamıştır (Perez-Gomez ve diğ., 2008). Pliometri ve ağırlık antrenmanının etkilerini araştıran başka bi çalışmada, pliometri antrenmanı sıçrama yüksekliğini SJ, CMJ, ve DJ'de anlamlı derecede artırırken, ağırlık antrenmanı grubu sıçrama yüksekliğini sadece SJ'de artırmıştır (Kubo ve diğ., 2007). Farklı pliometri egzersizlerini kullanan çalışmada 12 haftalık program sonrası CMJ antrenman grubunda yalnızca SJ ve CMJ yüksekliğinde anlamlı artış bulunurken, DJ antrenman grubunda SJ, CMJ ve DJ yüksekliğinde anlamlı artış bulunmuştur (Gehri ve diğ., 1998). Görüldüğü gibi, Kimi çalışmada kuvvet ve pliometri egzersiz oranına göre gelişim oranı değişmekte (Kubo, ve diğ., 2007; Perez-Gomez ve diğ., 2008), kimi çalışmada ise gelişim için uzun süre ve yüksek şiddetli antrenman gerekmektedir (Gehri ve diğ., 1998). Bu çalışmada ise normokside uygulanan aynı antrenmana hipoksi faktörünün eklenmesi ile sıçrama yüksekliklerinde neredeyse iki katına yakın gelişim elde edilmiştir. Hipokside yapılan pliometri dışındaki antrenman yöntemleri ile elde edilen sonuçlar ise çeşitlilik göstermektedir. Lokal hipoksi sıçrama perfromansına katkı sağlamazken (Abe ve diğ., 2005; Haruhiko ve diğ., 2011; Ismail, 2014), içerisinde patlayıcı güç egzersizleri içeren hipokside tekrarlı sprint antrenmanı bu çalışmadaki gibi normoksi gruba kıyasla hipoksi grupta daha büyük gelişmeler göstermiştir (Brocherie ve diğ., 2015). Hipobarik ortamda 4 haftalık kuvvet antrenmanı uygulanan başka bir çalışmada, kuvvet antrenmanı içerisinde pliometrik egzersizler de kullanılmıştır. Hipokside uygulanan kuvvet antrenmanı SJ'de 4.33cm ve CMJ'de 2.11 cm istatistiksel olarak anlamlı olmayan artış sağlamıştır. Aynı antrenmanı normokside uygulayan grup da SJ'de 1.89cm ve CMJ'de 3.26cm anlamlı olmayan artış sağlamıştır. (Álvarez-Herms ve diğ., 2014). Bunun aksine, bu çalışma hipokside salt bir pliometri antrenmanı uygulayan ilk çalışma olarak, hipoksi grubunda daha yüksek olmak üzere her iki antrenman grubunda anlamlı gelişimler göstermiştir. Yapılan bir analizde dikey sıçrama yüksekliğindeki gelişimin diğer egzersiz tipleriyle birleştirildiğinde daha iyi sonuç vermediğinden bahsedilirken (de Villarreal diğ., 2009), pliometri antrenmanının hipoksi ile birleştirilmesinin sıçrama performansında anlamlı gelişim sağladığı bu çalışma sonuçlarında açıkça görülmektedir.

Çalışmada hem pliometri egzersizlerinin hem hipoksinin anaerobik performans üzerinde etkilerinin olduğu görülmektedir. Hipoksi ve normokside uygulanan pliometri antrenmanı Wingate testinden elde edilen peak power (maksimum güç) ve relative peak power (rölatif maksimum güç) değerlerinde anlamlı gelişim göstermiştir. Peak power ve min. power (minimum güç) değerleri hipoksi grubunda daha yüksek bulunurken, average power (ortalama güç) değerinin normoksi grupta daha iyi olduğu tespit edilmiştir. Yüksek şiddetli aktivitelerin kısa sürede maksimal kuvvet üretme ve yüksek seviyede anaerobik güç gerektirdiği bilinmektedir (Álvarez-Herms ve diğ., 2014). Bu bilgi pliometri antrenmanın etkisine bir gerekçe olarak gösterilebilir ancak hipoksinin etkisinden bahsetmek için farklı gerekçeler üzerinde durmak gerekmektedir. Yükseltide, anaerobik egzersiz performansındaki gelişmelerin seyrelmiş hava ile alakalı olarak azalmış sürükleme etkisinden kaynaklı olabileceği belirtilmektedir (Hoffman, 2002). Fakat bu çalışmada anaerobik güçteki gelişmelerin havanın sürükleme etkisinin azalmasıyla alakalı olduğu söylenemez çünkü çalışmada gerçek bir yüksek irtifa yerine normobarik hipoksi uygulaması kullanılmıştır. Bu yüzden mevcut çalışmadaki gelişmelerin, anaerobik metabolizmanın daha fazla uyarılması ile ve anaerobik yollarla enerji üretiminin artışı ile alakalı olabileceği düşünülmektedir (Álvarez-Herms ve diğ., 2014). Ayrıca literatür artan kas tampon kapasitesini anaerobik performans gelişimine bir gerekçe olarak göstermektedir (Álvarez-Herms ve diğ., 2014). Hatta, yükseltinin anaerobik aktivitelere zarar vermediğini aksine onları geliştirdiğini ileri sürmektedir (Kenney ve diğ., 2011). Çünkü akut hipoksi anaerobik alaktik ve laktik enerji üretiminde etkiye sahip değildir (Wolski ve diğ., 1996). Bu nedenle 2 dakikadan kısa süren anaerobik performanslar düşük PO_2'den etkilenmemektedir (Fox ve diğ., 1988; McArdle ve diğ., 2009; Powers & Howley, 1996). Bu yüzden de hipoksi ve normoksi grupları arasında anaerobik maksimum güç değerleri arasındaki farkın hipoksi grubundaki muhtemel bir antrenman şiddeti artışından ziyade artan kas tampon kapasitesi ve anaerobik metabolizmadaki gelişmelerden kaynaklı olabileceği düşünülmektedir. Çünkü antrenmanın iş yükü her iki grupta eşit tutulmuştur ve literatür anaerobik performansın düşük PO_2'den etkilenmediğini söylemektedir.

Hipoksi grubunun 60°/sn açısal hızlarda alınan ölçümlerde, Flex. peak power (fleksiyon maksimum güç) değerinde kontrol grubundan, Ext.maxTorque (ekstansiyon maksimum tork) değerinde ise normoksi grubundan anlamlı derece daha iyi olduğu bulunmuştur. Flex. maxTorque (fleksiyon maksimum tork) ve Flex. peak power değerlerinde sadece hipoksi grubu anlamlı gelişme göstermiştir. 180°/sn açısal hızdaki ölçümlerde ise, Relative Flex. maxTorque (rölatif fleksiyon maksimum tork) hipoksi grubunda kontrol grubuna kıyasla anlamlı derecede daha yüksek bulunmuştur. Flex. peak power sadece hipoksi grubunda anlamlı artış göstermiş ve normoksi ve kontrol gruplarına kıyasla, hipoksi grubunda anlamlı derecede daha yüksek bulunmuştur. Hipoksi kaynaklı kuvvet gelişiminin nedeni çoğunlukla tip II motor ünite katılımındaki artışa dayandırılmaktadır (Manimmanakorn ve diğ., 2013; Park ve diğ., 2010). Literatürde diğer bir muhtemel sebep ise büyüme hormonudur (Teramoto & Golding, 2006). Fakat bu çalışmadaki hipoksi grubunda görülen diz fleksiyon ve ekstansiyon kuvvet gelişiminin nöral gelişimden kaynaklı olabileceği düşünülmektedir. Çünkü direnç antrenmanlarının 6-8 hafta gibi ilk evrelerindeki kas kuvveti gelişiminden esas sorumlu olan mekanizma nöral adaptasyonlardır ve sonraki evreler ise hızlı kas lif tipi dönüşümüne ve hipertrofide artışlara neden olur (Bird ve diğ., 2005).

Sonuç olarak, aynı egzersiz programı (aynı set ve tekrar sayısı ile) her iki antrenman grubunda aynı süre ile uygulanmasına ragmen, gelişim oranı hipoksi grubunda daha yüksek bulunmuştur. Ayrıca, kuvvet antrenmanları ile kombin edilen diğer antrenman türlerinin aksine, benzer gelişimler ekstra zaman harcamadan ve ağır yükler altına girmeden elde edilmiştir. Çalışmada, vücut kompozisyonunda anlamlı farklılık bulunmamasına karşılık hipoksi grubunda kuvvet değerlerinde görülen artışlar ve sprint ve sıçrama değerlerinde de hipoksi grubunun daha yüksek gelişimler göstermiş olması, gelişmelerin hipertrofiden ziyade nöral adaptasyondan kaynaklandığını desteklemektedir. Ayrıca, patlayıcı güç antrenmanındaki hızlı kas hareketlerinin, sinir sisteminin nöral katkısında artışa ya da az miktarda hipertrofi katkısıyla motor ünite ateşleme modelinin senkronizasyonuna yol açtığı (Bompa, 1999) ve SSC'den elde edilen patlayıcı kuvvetin, sinir sistemini diğer antrenman türlerinin çoğundan daha fazla uygulamaya koyduğu (Bağırgan, 2013) bilinmektedir. Bu bilgi normoksideki pliometri antrenmanının etkileri adına bilinen bir bilgidir ancak bu çalışmada görülmüştür ki hipoksi, bu nöral gelişimin katkılarını artırmaktadır. Literatür, hipoksik ortamın patlayıcı hareketlerin hızı ve kuvvetinde artışlar ve hipertrofideki gelişmeler sağlayarak kas performansının iyileştirilmesinde potansiyel avantaj sağladığını fakat normobarik hipoksi (gerçek yüksek irtifada olmayan) gelişmelerin halen netleştirilmeye ihtiyaç duyduğunu bildirmektedir (Feriche ve diğ., 2017). Bu çalışma sonuçları ile, normobarik hipoksinin de özellikle patlayıcı aktivitelerde, yüksek olasılıkla nöral gelişmelere dayanan performas artışında etkili bir yöntem olduğu sonucuna varılabilir.

Öneriler

1. Pliometrik antrenmanın LHTL (Live High, Train Low) ve LHTH (Live High, Train High) gibi farklı hipoksi modelleri ile denenmesi, ve literatürün anaerobik aktivitelerin yüksek irtifada daha avantajlı olduğunu desteklemesinden dolayı, pliometrik antrenmanın yüksek irtifada incelenmesi önerilmektedir.
2. Hipokside pliometri antrenmanın etkileri daha büyük bir örneklem grubu ile de araştırılmalıdır.
3. Katılımcıların beslenme alışkanlıkları mümkün olduğunca kontrol altına alınmaya çalışılmalıdır.
4. Daha kısa süreli (<8 hafta) pliometrik hipoksi antrenmanın etkileri araştırılmalı ve benzer gelişmeler elde edildiği taktirde kısa sürede hızlı gelişim gerektiren yarışmaların hazırlık dönemi için tavsiye edilebilmelidir.
5. Gelecek çalışmalar için nöral aktivite ve hipertrofinin ölçülmesi ve kas lif tipi dönüşümünün olup olmadığının incelenmesi önerilmektedir.
6. Hipokside pliometri antrenmanı, ilerleyen çalışmalarda elit sporcular gibi farklı popülasyonlara da uygulanmalıdır. Ayrıca kadınlarda ve farklı yaş gruplarında etkileri araştırılmalıdır.
7. Çalışmanın etkileri, farklı hipoksi seviyelerinde ve farklı pliometri egzersizleri ile denenebilir. Ayrıca farklı spor branşlarındaki antrenmanlara ilave olarak yapılacak uygulama türünün etkileri de araştırılmalıdır.

APPENDIX E. TEZ İZİN FORMU / THESIS PERMISSION FORM

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Soyadı / Surname : COŞKUN
Adı / Name : Betül
Bölümü / Department : Beden Eğitimi ve Spor Bölümü / PES

<u>**TEZİN ADI /** TITLE OF THE THESIS</u> (**İngilizce** / English): THE EFFECTS OF PLYOMETRIC TRAINING IN NORMOBARIC HYPOXIA ON BODY COMPOSITION, ANAEROBIC PERFORMANCE, STRENGTH, AND EXPLOSIVE POWER

<u>**TEZİN TÜRÜ**</u> **/** <u>DEGREE**:**</u> **Yüksek Lisans** / Master ☐ **Doktora** / PhD ☒

1. **Tezin tamamı dünya çapında erişime açılacaktır. /** Release the entire work immediately for access worldwide. ☐
2. **Tez <u>iki yıl</u> süreyle erişime kapalı olacaktır.** / Secure the entire work for patent and/or proprietary purposes for a period of **<u>two years</u>. *** ☐
3. **Tez <u>altı ay</u> süreyle erişime kapalı olacaktır.** / Secure the entire work for period of **<u>six months</u>**. ***** ☒

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