ผลของการตอบสนองในการหายใจต่อภาวะพร่องออกซิเจนหลังผ่านการฝึกสภาวะพร่องออกซิเจนที่ระดับความดันบรรยากาศต่ำเมื่อเทียบกับการฝึกแบบมาตรฐานในทหารพลร่มไทย

เรืออากาศตรีหญิงวีณา วิชพันธุ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาเวชศาสตร์การกีฬา
คณะแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2552

EFFECT OF HYPOBARIC HYPOXIC TRAINING ON HYPOXIC VENTILATORY RESPONSE IN THAI MILITARY AIRBORNE COMPARED WITH STANDARD TRAINING

Plt.Off.VEENA VIJABUND

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Master of Science Program in Sports Medicine

Faculty of Medicine

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Academic Year 2009

Thesis Title	EFFECT OF HYPOBARIC HYPOXIC TRAINING ON HYPOXIC VENTILATORY RESPONSE IN THAI MILITARY AIRBORNE COMPARED WITH STANDARD TRAINING.
By	Plt.Off.Veena Vijabund
Field of Study	Sports Medicine
Thesis Advisor	Associate Professor Sompol Sanguanrungsirikul, M.D.

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เรืออากาศตรีหญิงวีณา วิชพันธุ์ : ผลของการตอบสนองในการหายใจต่อภาวะพร่องออกซิเจนหลังผ่านการฝึกสภาวะพร่องออกซิเจนที่ระดับความดันบรรยากาศต่ำเมื่อเทียบกับการฝึกแบบมาตรฐานในทหารพลร่มไทย (EFFECT OF HYPOBARIC HYPOXIC TRAINING ON HYPOXIC VENTILATORY RESPONSE IN THAI MILITARY AIRBORNE COMPARED WITH STANDARD TRAINING.)
อ.ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.นพ.สมพล สงวนรังศิริกุล, 100 หน้า

วัตถุประสงค์ : เพื่อทดสอบผลการตอบสนองในการหายใจต่อภาวะพร่องออกซิเจนหลังผ่านการฝึกที่ระดับความดันบรรยากาศต่ำเมื่อเทียบกับการฝึกแบบมาตรฐานในทหารพลร่มไทย และทดสอบผลการฝึกที่ระดับความดันบรรยากาศต่ำเพื่อยืดระยะเวลาครองสติ

วิธีดำเนินงานวิจัย : ผู้เข้าร่วมโครงงานวิจัย ได้แก่ ทหารพลร่มของกรมปฏิบัติการพิเศษ กองทัพอากาศ ซึ่งได้รับการบรรจุหรือแต่งตั้งเป็นผู้ทำการในอากาศ ที่มีขีดความสามารถในการกระโดดร่ม และผ่านเกณฑ์การคัดเลือกเข้าศึกษาวิจัย จำนวน 28 คน อายุ 21-38 ปี และไม่มีโรคประจำตัวที่เป็นอุปสรรคต่อภารกิจทางการบิน โดยแบ่งออกเป็น 2 กลุ่ม ดังนี้ กลุ่มทดลอง (13 คน) และกลุ่มควบคุม (15 คน) ซึ่งทั้งสองกลุ่มจะถูกเก็บข้อมูลส่วนตัวทั้งหมด 3 รายการ คือ สมรรถภาพทางกายพื้นฐาน ค่าการตอบสนองต่อภาวะพร่องออกซิเจน และระยะเวลาครองสติ ทั้งช่วงก่อนเข้ารับการฝึกและภายหลังเข้ารับการฝึกของกลุ่มทดลอง โดยกลุ่มทดลองจะต้องเข้ารับการฝึกปรับสภาพร่างกายที่ระดับความดันบรรยากาศต่ำภายในห้องปรับบรรยากาศความกดดันต่ำ ซึ่งทำการฝึกเฉพาะตอนเช้าของวันราชการเท่านั้น ระยะเวลา 1 ชั่วโมง/คาบ/วัน ที่ระดับความสูง 10,000-12,000 ฟุต จำนวน 14 คาบ

ผลการทดสอบ : ระดับค่าการตอบสนองต่อภาวะพร่องออกซิเจนของกลุ่มทดลองมีค่าสูงกว่าและแตกต่างจากกลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) และกลุ่มทดลองมีระยะเวลาครองสติที่นานกว่ากลุ่มควบคุมอย่างมีนัยสำคัญทางสถิติ ($p<0.05$) นอกจากนั้นพบว่าค่าการตอบสนองต่อภาวะพร่องออกซิเจนของกลุ่มทดลองมีแนวโน้มลดลงเมื่อเวลาผ่านไป 1 สัปดาห์หลังเสร็จสิ้นการฝึก ถึงแม้ค่าดังกล่าวนี้จะลดต่ำลง แต่ยังคงมีระดับที่สูงกว่ากลุ่มควบคุมที่ไม่ได้รับการฝึกที่ระดับความดันบรรยากาศต่ำอย่างชัดเจน

สรุปผลการทดสอบ : การฝึกที่ระดับความดันบรรยากาศต่ำสามารถเพิ่มผลการตอบสนองในการหายใจต่อภาวะพร่องออกซิเจน และสามารถยืดระยะเวลาครองสติให้นานขึ้นได้ เมื่อเทียบกับการฝึกแบบมาตรฐานในทหารพลร่มไทย ซึ่งวิธีการฝึกนี้เหมาะสำหรับการเตรียมความพร้อมทางด้านร่างกายในทหารพลร่มไทย เพื่อปฏิบัติภารกิจการบินทางทหารที่มีระยะเวลาทำการไม่เกิน 1 สัปดาห์

สาขาวิชา เวชศาสตร์การกีฬา ลายมือชื่อนิสิต ....
ปีการศึกษา 2552 ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก ....

4974779430 : MAJOR SPORTS MEDICINE

KEYWORDS : HYPOBARIC HYPOXIC TRAINING / HIGH ALTITUDE / MILITARY AIRBORNE

Plt.Off.VEENA VIJABUND : EFFECT OF HYPOBARIC HYPOXIC TRAINING ON HYPOXIC VENTILATORY RESPONSE IN THAI MILITARY AIRBORNE COMPARED WITH STANDARD TRAINING. THESIS ADVISOR: ASSOC.PROF. SOMPOL SANGUANRUNGSIRIKUL, M.D., 100 pp.

Introduction: The objective of this study is to examine the effect of hypobaric hypoxic training on hypoxic ventilatory response (HVR) and extending the duration of time of useful consciousness (TUC) in Thai military airborne compared with the standard training. **Methods**: Total 28 subjects of Royal Thai Air Force Special Operations Regiment were recruited and deivided into two groups as the trained and untrained group. There are 13 and 15 airborne troopers in the first and second groups, respectively. The baseline physical characteristics, HVR and TUC were collected for the pre-test in both groups. Only the trained group was trained in the hypobaric chamber of Insititute of Aviation Medicine for 14 training sessions with the intermittent hypobaric hypoxic training. The training duration was 1 hour per session per day. This intermittent training program was continued only on the official working day and paused on the weekend day. **Results**: The averaged value of HVR in the trained group showed the statistic significant differences ($p<0.05$) and higher than the untrained group. The duration of TUC could be extended in the trained group with the significant difference ($p<0.05$) after the 14 training sessions were completed. The trend of HVR declined gradually after 1 week of the training accomplishment in the trained group. **Conclusion**: The intermittent hypoxic hypobaric training could increase the hypoxic ventilatory response and extend the duration of TUC significantly. This training program supported the aviation safety and was proper for preparing the airborne troopers for the exclusive military airborne missions which the duration of the missions did not exceed than 1 week.

Field of Study : Sports Medicine Student's Signature Veena Vijabund

Academic Year : 2009 Advisor's Signature Sompol Sanguanrungsirikul

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Finally, I am thankful to my commanders and colleagues in the Armed Forces Academies Preperatory School and the Sports Fitness Division in Sports Science Department of Sports Authority of Thailand and all my best friends in Satit Chulalongkorn Demonstrations School (CUD'37) and the Master program of Sports Medicine Faculty of Medicine Chulalongkorn University for their loves, assistance, sincerity, friendship, encouragement, and support during my educational experience in this program.

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CHAPTER I
INTRODUCTION

Background and Rationale

Hypobaric hypoxic hypoxia is the physiological problem when individuals travelled to the higher altitudes. This serious problem also occurred in a large group of the military airborne personnel around the world. Douglas S. et al. (2005) reported that the aircrews of the U.S. Navy and Air Force were affected by hypoxia alone 221 incidents and other 199 incidents involving hypoxia. There are from total 1055 incidents. Especially, twelve incidents were shown below 14,000 feet above groud level.

From the pilot study (Appendix H) by collecting the questionair in the 2008 Thai Military Sports Compettition showed that 3.7% had the hypoxic symptoms in the cabin before jumping out of the aircraft, 0.7% had the hypoxic symptoms during holding their free fall position in the air, 1.5% realized these symptoms after the parachutes were deployed. Furthermore, the self-evaluated readiness before flight score of the previous airborne missions showed that only 37.8% of the airborne personnel who had a perfect conditions of the physical fitness before the regular airborne operations.

Since World War II, the hypobaric chamber training is the technological methodology in most Air Forces for recognizing the incidents of the altitude illness (Smart TL. et al., 2004). It simulated the high altitude environments for studying and learning the high altitude physiology. The familiarity to the low barometric pressure condition and the improvement of the hypoxic ventilatory response (HVR) are very important for people who related to high altitudes (Townsend NE. et al., 2002 ; Tansey EA., 2008).

The hypoxic ventilatory response (HVR) is the increase in ventilation induced by hypoxia. It is initially elevated in the lowlanders who go to high altitude, although it reduces significantly over time as people acclimatize (The Natural History of Humankind, 2008). Bernardi L. et al. (2006) researched that a high hypoxic ventilatory response could help the sojourns to climb further and work at high altitude. It was believed that extreme altitudes could be tolerated without oxygen by the individuals had a high hypoxic ventilatory response. HVR caused the mechanisms which removed the cabondioxide and increased the arterial oxygen partial pressure by increasing the ventilation. HVR increased the cerebral blood flow. It was due to the vasodilatory effects which washed out CO_2 resulting in alkalosis. It resulted in the drive and led to decline in the ventilation (Andrea V. et al., 2004).

Katayama et al. (2000) stated that the hypoxic ventilatory response (HVR) was an index of the ventilatory chemosensitivity to hypoxia. The chronic exposure to hypoxia lead to increase the resting HVR accompanied by increases in pulmonary ventilation and SaO_2 at rest and during exercise in hypoxia. A high HVR was one of the factors that minimized O_2 desaturation at high altitude during acclimatization.The chronic hypoxic exposure of sojourns at high altitudes could lead to increase in the resting hypoxic ventilatory response (Schoene et al.,1990).

The previous study of Katayama et al. (1998) have shown that the repeated bouts of hypoxic exposure can increase the hypoxic ventilatory response in humans. The repeated bouts of hypoxia are termed as an intermittent hypoxic training. In some study has shown the effects of intermittent hypoxic exposure on HVR at sea level which were investigated in humans (Garcia et al., 2000; Katayama et al., 2001). It indicated that the short-termed intermittent hypoxic exposure could increase the HVR (Katayama et al, 2002). The resting HVR increased after the short-term intermittent hypoxic exposure without endurance training which utilized for the pre-acclimatization before climbing to high altitude (Katayama et al., 2000). Most of the intermittent hypoxic training programs last at least 5 days and consist of approximately 60 minute per day at the simulated altitudes of 11,400-16,500 ft. (3800–5500 m.). Intermittent hypoxic protocols have a number of potential benefits. It has been shown to increase exercise ventilation and saturation in hypoxia (Katayama et al., 2001), and to reduce the severity of acute mountain sickness (Beidleman et al., 2004).

Grant S. et al. (2002) studied the effect of the simulated altitude by the hypobaric chamber with the hypoxic ventilatory response. They found that a good sensitivity of the hypoxic ventilatory response was an advantage for people who travelled to high altitude. The effect of HVR had gone within 1-2 weeks which is not a good benefit for the mountaineers.

The airborne personnel are mostly in the Special Forces and ready for a variety of combats. They are a group of people who take a high risk of hypobaric hypoxic hypoxia during facing the real hypobaric natural air outside the aircraft with and without the oxygen supplements. From the retrospective survey of Smith A. (2005), the physical activities accelerated the onset on hypoxic hypoxia. As similar to the other study which found that the military helicopter operations were evaluated to be equal to the moderate and vigorous physical activity. These high loaded activities affected certainly the air crews, especially in the non-pilot aircrews such as loadmasters and pararescuemen. The workload of loadmasters may reach 430 watt to 500 watt for short periods during routine sorties in flight such as door-gunning and recovery of the fast ropes. The effects of hypoxia were found in most healthy individuals after reaching 10,000 feet. Hypoxia may appear at altitude lower 10,000 feet due to the individual differences in susceptibility (Hackworth CA. et al, 2003).

Following the public journal in the Royal Thai Air Force Day (2010) the future vision of the Royal Thai Air Force is to be one of the best Air Force in ASEAN in this decade. Therefore, the Royal Thai Air Force have a strong determination to improve the capability of their personnel to be in a high universal level. This is the reason why Thai military airborne personnel have to prepare themselves for the unexpected future missions all the time. Because of the unique nature of the airborne sorties, Thai military airborne personnel attended the recurrent simulated altitude chamber training at 25,000 feet for the recognition of hypoxic hypoxia incidents every 3 years by the Institute of Aviation Medicine, Royal Thai Air Force. Due to the fact that the intermittent hypobaric hypoxic training is the alternative way for reducing the risks of hypoxia in flight (Katayama et al., 2001), the reasearcher tried to find the suitable protocols to promote the Aviation Safety for the airborne personnel and examine the inventional hypoxic training protocol which whether was proper for Thai military airborne operations.

For promoting the Aviaion Safety in Thai military airborne operations, the purpose of the present study was to examine the effect of hypobaric hypoxic training on hypoxic ventilatory response in Thai military airborne compared with the standard training. The one-week results were followed for proving the effect of this protocol.

Research Questions

1.Can the hypobaric hypoxic training increase the hypoxic ventilatory response in Thai military airborne ?

2.Can the effect of the increased hypoxic ventilatory response extend the duration of time of Useful Consciousness in Thai military airborne ?

3.How long does the effect of the hypobaric hypoxic training on the hypoxic ventilatory response exist ?

Objectives

To examine the effect of hypobaric hypoxic training on hypoxic ventilatory response and the capability to extend the time of useful consciousness in Thai military airborne compared with standard training.

Hypothesis

The hypobaric hypoxic training can increase the hypoxic ventilatory response and extend the time of useful consciousness in Thai military airborne.

Scope of Research

This study is an experimental research design which analyze the effect of hypobaric hypoxic training on hypoxic ventilatory response in Thai military airborne compared with standard training. All subjects were the military airborne of Royal Thai Air Force.

The study approval was obtained from the Chulalongkorn University Ethics Committee. All subjects wrote their informed consent before participating in this study. The clear details of this research procedure and risk were revealed to subjects.

Assumptions

1. All measurement devices were calibrated for the standard accuracy and reliability.
2. Subjects should have their physical fitness in a good condition for aviation mission along this project.
3. Participants should sleep at least 6-8 hours per day before training in a hypoxic environment.
4. To avoid having a meal more than 2 hours before training and testing.
5. All subjects were asked to refrained from smoking and drinking alcohol and caffeine more than 6-8 hours before training.

Limitations

1. All participants have to pass the inclusive criteria of this study and pass the Aviation Medicial Examination for the airborne troopers of the Institute of Aviation Medicine, Royal Thai Air Force.
2. Subjects were qualified to be the military airborne personnel of Royal Thai Armed Force.
3. Participants should not have any diseases before and during this training program.
4. Subjects should have their physical fitness in a good condition for the aviation mission along this project.
5. The subjects have to participate in the fundamental high altitude physiology course of the Institute of Aviation Medicine, Royal Thai Air Force.
6. Due to the hypobaric chamber in this project is belong to the Institute of Aviation Medicine, Royal Thai Air Force, the researcher have to pause the hypobaric

hypoxic training schedule in the official holiday and the national holiday but not more than 3 days consecutively.

7. Participants were allowed to continue the official military duty in their responsibility along this project, but not more than 1 days consecutively.

Key Words

1. Hypobaric Hypoxic Training
2. High Altitude
3. Military Airborne

Operational Definitions

Time of Useful Consciousness (TUC)

TUC is the duration of the individual consciousness in the hypobaric hypoxic environment. This duration is counted when individual have inspired the less oxygen air or stayed in the hypoxic environment. Along this period, they will gradually loose their function and coordination. The time of TUC is recorded when subjects is unlocking the oxygen mask. The time is stopped counting when individual has been showing a first sign or symptom. The unit of the time of TUC is minute.

The volunteers will do the coordinated exercise test by doing a form fitter toy for children over 18 months. They have to match shapes and textures with the specific holes in the cube during staying in the hypoxic environment.

The time will be stopped recording when they have been showing the first signs of the hypoxic hypoxia during playing the form fitter toy. Their first signs are judged by the flight surgeon of the Institute of Aviation Medicine of Royal Thai Air Force inside the chamber. They will be worn the oxygen mask suddenlly.

Expected Benefits and Applications

1. To test the effect of the hypobaric hypoxic training for increasing the hypoxic ventilatory response in Thai military airborne troopers.
2. To test the capability of the short-intermittent hypobaric hypoxic training program, which is the alternative method for saving the budgets of the Royal Thai Air Force, on the hypoxic ventilatory response in Thai military airborne.
3. To prescribe the proper methods and durations of the hypoxic training program for certainly increasing the hypoxic ventilatory response in Thai military airborne.
4. To promote the Safety Aviation Policy of Royal Thai Air Force.
5. To reduce the risk of a hypoxic hypoxia and prevent the accidents which associated with the leakage of the pressurized cabin.
6. To promote the eligible retirement age for the Thai airborne personnel.
7. To prepare and support the troops for the airborne missions.
8. This data can be the valuable infomation for the furher studies.

Conceptual Framework

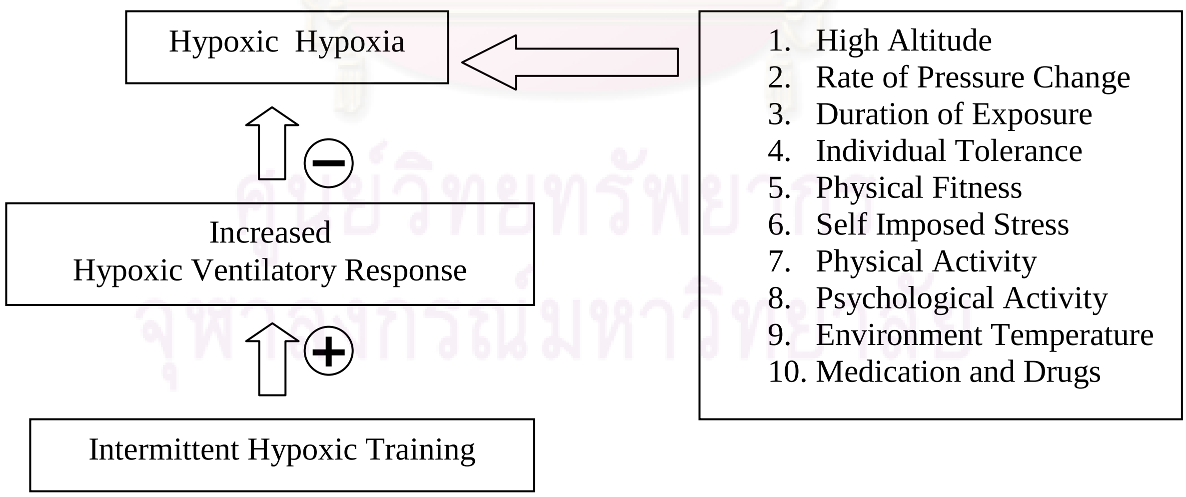


Figure 1.1 Conceptual Framework

CHAPTER II

REVIEW LITERATURES

High Altitude and Physiology

Rick Curtis (1995) stated that altitude is defined on the following scale.

- High level is at 8,000 - 12,000 feet (2,438 - 3,658 meters).
- Very high level is at 12,000 -18,000 feet (3,658 - 5,487 meters).
- Extremely high level is over than 18,000 feet (over 5,500 meters).

There are no specific factors such as age, sex, or physical condition that correlate with susceptibility to altitude sickness. Some people are more susceptible to altitude sickness than others who can acclimatize.

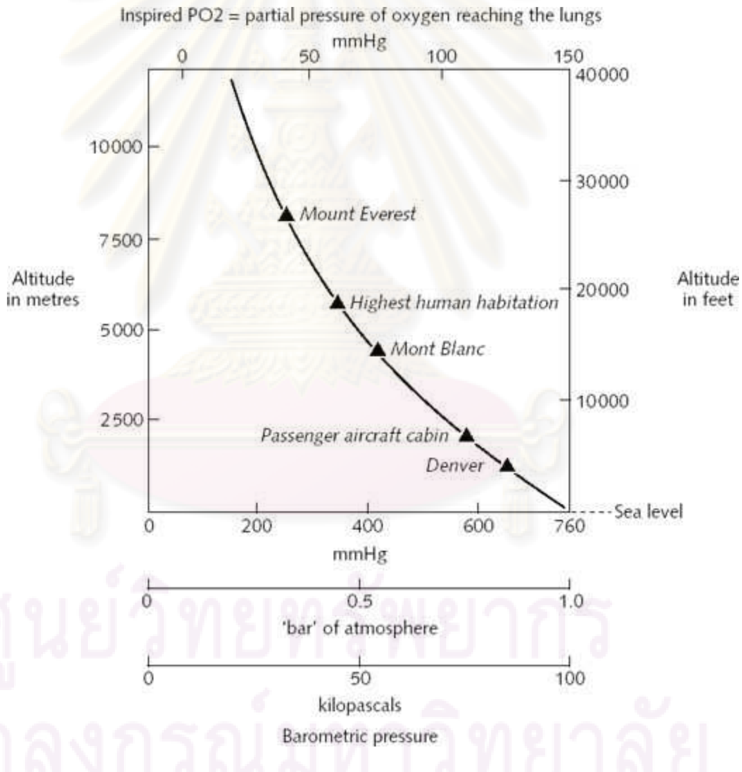


Figure 2.1 Atmospheric Pressure Change and Altitude

(Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

In high altitude environment, the concentration of oxygen is about 21% as same as the ground level, but the number of oxygen molecules per breath is reduced. As the barometric pressure decreases, the partial pressure of oxygen decreases proportionately. At 12,000 feet (3,658 meters), the barometric pressure is only 483 mmHg. There are roughly 40% oxygen molecules per breath. In order to compensate the proper oxygen to the body during high altitude, the breathing deep rate has to increase for gaining the oxygen content in the blood.

Adaptation to High Altitude

The body's response to the low PO_2 at altitude is to produce additional red blood cells to compensate for the desaturation of haemoglobin. In the mining community of Morococha, Peru, where people reside at altitudes above 4,540 meters, haemoglobin levels of 211 mg/dl have been measured, in contrast to the normal 156 mg/dl of the sea-level resident in Lima. This higher haemoglobin compensates rather completely for the low PO_2 at those altitudes.

Sea Level: 156 mg/dl times 1.34 ml O_2/g at 98% saturation = 224 ml /l

4,540 m: 211 mg/dl times 1.34 ml O_2/g at 81% saturation = 224 ml/l

Probably the best test of the degree to which these high-altitude residents have adapted is found in the Vo_2 max values measured at altitude. Average values of 46 to 50 ml/kg* min were measured on the altitude natives, which compares favourably with sea-level natives in that country and in ours. In addition, recreational runners at 3,600 meters have been shown to have VO_2 max values similar to their sea-level counterparts.

There is no question that any sea-level resident who makes a journey to altitude and stays a while will experience an increase in red blood cell number. However, the adaptation will probably never be complete. This conclusion is drawn from a study that compared VO_2max values of several different groups: (a) Peruvian lowlanders and Peace Corps volunteers who came to altitude as adults, (b) lowlanders who came to altitude as children and spent their growing years at altitude, and (c) permanent altitude residents. The VO_2max values were 46 ml/kg*min for the altitude residents and those who arrived there as children. In contrast, the lowlander who arrived as adults and spent only one to four years at altitude had values of 38ml/kg*min. This indicates that in order to have complete adaptation must spend the developmental years at high altitude. This may help explain the surprisingly good performance of Kipchoge Keino's performance in the 1,500-meter run at the Maxico City Olympic Games mentioned earlier, since he spent his childhood at an altitude which was similar to Mexico City.

Human adapt to altitude by producing more red blood cells to counter the desaturation caused by the lower PO_2. Altitude residents who spent their growing years at altitude show a rather complete adaptation as seen in their arterial oxygen content and VO_2max values. Lowlanders who arrives as adults show only a modest adaptation.

Acclimatization

The major cause of altitude illnesses is going too high and fast. Giving time for the body can adapt to the decrease in oxygen molecules at a specific altitude. This process is known as acclimatization and generally takes 1-3 days at that altitude. For example, if you hike to 10,000 feet (3,048 meters), and spend several days at that altitude, your body acclimatizes to 10,000 feet (3,048 meters). If you climb to 12,000 feet (3,658 meters), your body has to acclimatize once again. A number of changes take place in the body to allow it to operate with decreased oxygen.

- The depth of respiration increases.
- Pressure in pulmonary arteries is increased, “forcing” blood into portions of the lung which are normally not used during sea level breathing.
- The body produces more red blood cells to carry oxygen,
- The body produces more of a particular enzyme that facilitates the release of oxygen from hemoglobin to the body tissues.

Hypoxia

The absence of an adequate supply of oxygen to the tissues, whether in quantity or molecular concentration, is termed hypoxia. Humans are extremely sensitive and vulnerable to the effects of deprivation of oxygen, and severe hypoxia nearly always results in a rapid deterioration of most bodily functions: eventually it will lead to death.

Tissue hypoxia are recognized and classified in four types according to the primary mechanism involved. These types are:

1.Hypoxic Hypoxia

Hypoxic hypoxia is the result of a reduction in the oxygen tension in the arterial blood and the capillary blood. The aetiology includes the low oxygen tension of inspired gas associated with exposure to altitude: so-called hypobaric hypoxia.

Other causes are the hypoventilatory states (e.g. paralysis of respiratory musculature, depression of central control of respiration, airway obstruction and pulmonary atelectasis (including that due to exposure to high sustained accelerations)); the impairment of gas exchange across the alveolar-capillary membrane (e.g. pulmonary oedema and pulmonary fibrosis); the impairment of the circulation with right to left shunts as may occur with the congenital or acquired communications, and ventilation-perfusion mismatches (e.g. chronic bronchitis and emphysema).

2.Anaemic Hypoxia

Anaemic hypoxia is the consequence of a reduction in the oxygen-carrying capacity of the blood. Thus although arterial oxygen tension is normal, the amount of haemoglobin available to carry oxygen is reduced. The oxygen tension of the blood falls more rapidly than normal as it flows through the capillary beds and so, at their venous ends, it is inadequated to maintain the required minimum level throughout the tissue involved. Causes of anaemic hypoxia include a reduced erythrocyte count (e.g. haemorrhage, increased red cell destruction, decreased red cell production), a reduced haemoglobin concentration (e.g. hypochromic anaenia), synthesis of abnormal haemoglobin (e.g. sickle cell anaemia), a reduced oxygen-binding capability (e.g. carbon monoxide inhalation), and chemical alteration of haemoglobin (e.g. methaemoglobinaemia).

3.Stagnant Hypoxia

Ischaemic hypoxia is the consequence of a reduction in blood flow through the tissues. Gas exchange in the lungs and the oxygen tension and content of the arterial blood are normal but oxygen delivery to the tissues is inadequate. This is an example of tissue hypoxia in the absence of arterial hypoxaemia. There is increased oxygen extraction and the oxygen tension falls to a low level in the venous ends of the capillaries. Causes of ischaemic hypoxia include local arteriolar constriction (e.g. exposure of digits to cold), obstruction of arterial supply by disease or trauma, and general circulatory failure (e.g. cardiac failure, vasovagal syncope, and the fall in cardiac output and blood pressure associated with exposure to high sustained accelerations). Oxygen therapy is of little use in such forms of hypoxia.

4.Histotoxic Hypoxia

Histotoxic hypoxia is the result of an interference with the ability of the tissues to untilize a normal oxygen supply for oxidative processes. An example is cyanid poisoning in which the action of cytochrome oxidase of the mitochondria is completely blocked, even in the presence of adequate molecular oxygen. Certain vitamin deficiencies, for example, beri-beri resulting from inadequate intake of vitamin B1, will have the effect of compromising several stages in the untilization of oxygen by the tissues. Furthermore, oxygen toxicity, a condition in which an excessive tissue pressure of oxygen occurs itself gives rise to a failure of oxidative metabolism.

Hypoxic hypoxia as a result of a reduction in the oxygen tension in the inspired gas is the most common form oxygen deficiency which occurs in aviation. However, other forms of hypoxia can do occur in aviation, for example, anaemic hypoxia produced by carbon monoxide poisoning, the ischaaemic hypoxia produced by exposure to cold, and the stagnant hypoxia produced by sustained accelerations. It should be remembered that one or more forms of hypoxia may occur concurrently.

Acute Hypobaric Hypoxia : Hypoxia in Flight

Hypobaric hypoxia is generally recognized to be the most serious single physiological hazard during flight at altitude since breathing ambient air on ascent will result in a fall in the molecular concentration, and thus the partial pressure, of oxygen in the lung. Even the 25% reduction in the partial pressure of oxygen in the atmosphere associated with ascent to an altitude of 8,000 feet produces a detectable impairment in some aspects of mental performance; whilst sudden exposure to 50000 feet as a consequence of rapid decompression, which reduces the partial pressure oxygen within the lungs to 10% of its sea-level value, will cause unconsciousness within 12-15 seconds and death in four to six minutes. In the past, lack of oxygen took a regular toll of both lives and aircraft; many military aircrew were killed by hypoxia in flight, whilst the ability of many more to perform their duties was impaired by the condition. As a result military aircrew generally receive detailed training on this topic and the opportunity to gain personal experience of hypoxia under controlled conditions in hypobaric chambers. Furthermore, the world of civilian flying is not exempt from this hazard although the aircrew may not necessarily have had the same degree of person experience of hypoxia in training. Therefore, notwithstanding that improvements in the performance and reliability of cabin pressurization and oxygen delivery systems have greatly reduced incidents and accidents due to hypoxia they still occur and constant awareness and vigilance throughout the aviation community remains essential.

Aetiology

The principal causes of hypoxia in flight are:

1. Ascent to altitude without supplementary oxygen.
2. Failure of personal breathing equipment to supply oxygen at adequate concentration and/or pressure.
3. Decompression of the pressure cabin at high altitude.

Table 2.1 Relative incidence of the causes of 397 causes of hypoxia in flight in a military Air Force (Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

Cause of hypoxia	Relative Incidence (%)
Failure of oxygen supply	
- Line failure	2
- Low/depleted	1
Failure of oxygen regulator	25
Regulator off	1
Inadvertent break of connection in hose between regulator and mask	9
Hose defect or failure	1
Inadequate seal of mask to face	7
Malfunction of mask valves	3
Decompression of pressure cabin	32
Toxic fumes giving rise to hypoxia	2
Other	17

Note: The demand oxygen regulators used in this air force delivered safety pressure only at altitudes greater than 28000 feet.

The relative incidence of the various causes of hypoxia in flight over an 14-year period in a military air force is presented in Table 2.1. Failure of the oxygen regulator and decompression of the cabin together account for more than half the total number of reported incidents in this series.

Respiratory responses to acute hypobaric hypoxia

The time course of the physiological changes produced by breathing air at altitude is a function of the manner in which the condition is induces. Thus the common rate for an aircraft of 2000-3000 feet/min, failure of oxygen delivery equipment; and fastest following a rapid decompression. Although breathing air during a routine steady ascent is now an uncommon cause of hypoxia in professional aircrew, it does occur in leisure flying (such as in those flying light aircraft, gliders and balloons), and it is convenient to begin by describing the respiratory changes induced by hypoxia produced in this manner.

Alveolar gases when breathing air

The fall in partial pressure of oxygen in the inspired gas that occurs on ascent to altitude causes a progressive reduction in the alveolar oxygen tension. The main determinant of the difference in oxygen tension between inspired gas is the alveolar carbon dioxide tension. That can be demonstrated by rearranging the alveolar air equation thus:

$$P_{I_{O_2}} - P_{A_{O_2}} = P_{A_{CO_2}}\left(F_{I_{O_2}} + \frac{1 - F_{I_{O_2}}}{R}\right)$$

Where p_{Io2} *is inspired (tracheal) oxygen tension.* P_{Ao2} *is alveolar oxygen tension,* P_{ACO2} *is alveolar carbon dioxide tension,* F_{IO2} *is the fractional concentration of oxygen in the (dry) inspired gas, and the respiratory exchange ratio.*

A fall in alveolar carbon dioxide tension will reduce the difference between the oxygen tensions in the inspired and alveolar gases. The tension of carbon dioxide in the alveolar gas is itself determined by the ratio of carbon dioxide production to alveolar ventilation, and this ratio is independent of environmental pressure. Therefore, alveolar carbon dioxide tension remains constant on ascent to altitude, the ratio of carbon dioxide production to alveolar ventilation is unchanged. In practice, however, on acute exposure to altitude, alveolar carbon dioxide tension remains constant only between sea level and an altitude of 8000-10000 feet. Above this altitude, arterial oxygen tension falls to a level that stimulates respiration; and alveolar carbon dioxide tension is reduced by virtue of increased alveolar ventilation. Thus alveolar oxygen tension falls linearly with the decline in environmental pressure associated with an ascent from sea level to about 10000 feet but, above this altitude, the reduction in alveolar oxygen tension is less than it occurred if there was no increase in ventilation and no consequent fall in alveolar carbon dioxide tension. The changes in alveolar gas tensions associated with ascent to altitude when breathing air are shown graphically in Figure2.2

The increase in pulmonary ventilation produced by exposure to an altitude above 8000-10000 feet may be regarded as the resultant of two conflicting factors, that is, the low arterial oxygen tension stimulates ventilation through its effect on the chemoreceptor of the carotid and aortic bodies, but the increase in ventilation is opposed by the respiratory depressant effect of the concomitant reduction in carbon dioxide tension. The compromise strike between these two competing influences is the demand for an adequate oxygen supply versus the need to maintain a normal acid-base balance. The magnitude of the increase in ventilation, and hence the fall in alveolar carbon dioxide tension, exhibits considerable the individual variation. During acute exposures of subjects at rest, pulmonary ventilation at 18000 feet is 20-50% greater than that observed at sea level, whilst at 22000 feet it is 40-60% greater.

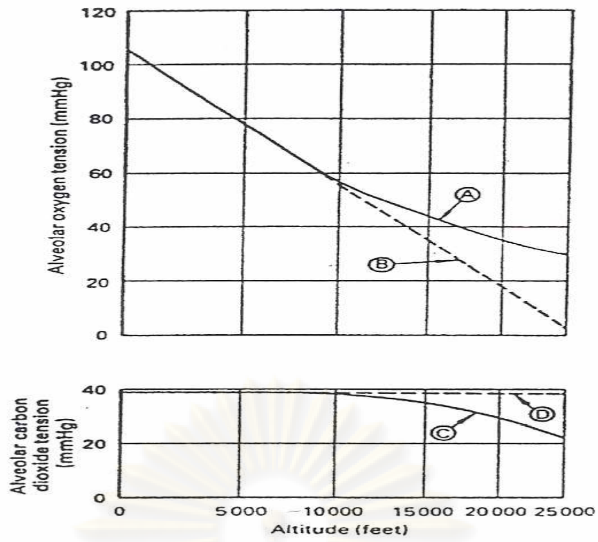


Figure 2.2 The effect of acute exposure to various altitudes

(Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

whilst breathing air, on the alveolar tensions of oxygen (curve A) and carbon dioxide (curve C). The curves describe the mean values for a group of 30 subjects seated at rest. The dashed lines indicate the values of alveolar tensions of oxygen (curve B) and carbon dioxide (curve D) which would be obtained if the hypoxia induced by ascent to altitude did not increase pulmonary ventilation.

The effect of altitude upon the ventilatory response to mild and moderate exercise is a greater proportional increase in pulmonary ventilation, and the effect can be demonstrated at altitudes as low as 3000 feet. The increase in pulmonary ventilation induced by exercise in the moderate hypoxia is that alveolar carbon dioxide tension is reduced below that produced by breathing air at rest at the same altitude. There is a corresponding rise in alveolar oxygen tension, perhaps by 3-5 mmHg.

The increase in pulmonary ventilation and cardiac output stimulated by the hypoxia arising from breathing the air at the altitudes up to about 20000 feet produces a small, almost insignificant, increase in the total oxygen consumption of the tissues, and in the carbon dioxide production by them. The fall in alveolar carbon dioxide tension produced by disproportionately rise in pulmonary ventilation, liberates carbon dioxide from the very substantial body stores of the gas. The output of carbon dioxide in the expired gas actually exceeds its metabolic production by the tissues. Thus, the respiratory exchange ratio (R) is raised at the beginning of an exposure to altitude when breathing the air. It slowly returns to the previous resting value as the excess carbon dioxide is removed from the body rages and a steady state is regained. For example, R is raised to just over 1.0 on acute exposure to the air at 18000 feet, and its normal resting value of 0.85 is not regained for 30-40 minutes. Clearly, a raised value of R will produce a higher alveolar oxygen tension for a given inspired oxygen tension and alveolar carbon dioxide tension than would otherwise be the cause; and so, in the example quoted, with an alveolar carbon dioxide tension of 28mmHg, alveolar oxygen tension will fall from about 41 mmHg at the beginning of the exposure to about 37 mmHg at the end.

The relationship between the alveolar tension of oxygen and carbon dioxide changes progressively throughout an exposure to a given altitude since the alveolar oxygen tension is determined by the level of alveolar carbon dioxide and the value of R, both of which are the functions of the intensity of the ventilatory response to hypoxia and the duration of exposure. The relationship between alveolar oxygen tensions and increasing altitude, with a period of 10-20 minute spent at each, is shown graphically in Figure 2.2. The same data are presented numerically in Table 2.2, where the considerable individual variability is indicated by the values of standard deviations. In general, the alveolar oxygen tension reduced, in short-duration exposures, to 45 mmHg at 15000 feet, to 40 mmHg at 18000 feet, to 35 mmHg at 21000 feet, and to 30 mmHg at 25000 feet.

Table 2.2 Mean values for alveolar gas tensions in 30 seated resting subjects after acute (10-20 minutes) exposure to breathing air at altitude. (Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

Altitude (ft)	Inspired Oxygen tension (mmHg)	Alveolar tensions (mmHg) of:			
		Oxygen		Carbon dioxide	
		Mean	SD	Mean	SD
0	148	103.0	5.5	39.0	2.5
8000	108	64.0	5.0	38.5	2.6
15000	80	44.7	5.0	30.5	2.7
18000	69	39.5	4.2	28.0	2.5
20000	63	36.5	4.0	26.5	2.5
22000	57	33.2	3.0	25.0	2.6
25000*	49	30.0		22.0	

After 3-5 minutes exposure.

Alveolar Gases when Breathing Oxygen

When 100% oxygen, has been breathed for several hours, virtually all the nitrogen has been washed out of the body tissues and alveolar gas, the relationship between the alveolar tensions of oxygen and carbon dioxide and the environmental pressure simplifies to:

$$P_{AO2} = (P_B - P_{H2O}) - P_{ACO2}$$

Where P_{AO2} is alveolar oxygen tension, P_B is environmental pressure, P_{H2O} is water vapour tension at 37°C (i.e. 47 mmHg), and P_{ACO2} is alveolar carbon dioxide tension.

Generally in aviation, however, the time for which 100% oxygen is breathed is less than two hours, and the alveolar gas still contains a small mount of nitrogen, sufficient to exert a tension of 3-5 mmHg. Thus, in practice the alveolar oxygen tension when breathing 100% oxygen is usually 3-5 mmHg less than that predicted by the equation. The alveolar carbon dioxide tension remains constant alveolar oxygen tension will fall linearly with environmental pressure (as it does up to 10000 feet when breathing air). When breathing 100% oxygen, however, it is not until an altitude of 33000-33700 feet is reached, the alveolar partial pressure of oxygen falls to 103 mmHg, that is, the value which was observed when breathing air at sea level. When an altitude of about 39000 feet is reached, breathing 100% oxygen, the alveolar oxygen tension falls to 60-65 mmHg (that is, to a similar value to that reached at 10000 feet breathing air). Above 39000 feet, the further fall in alveolar oxygen tension stimulates respiration, even though 100% oxygen is being breathed, just as it does above 10000 feet when breathing air. The alveolar oxygen tension rises by 1 mmHg for ever 1 mmHg reduction in alveolar carbon dioxide tension. Thus, for example, the alveolar carbon dioxide tension at 43000 feet is about 30 mmHg and the corresponding alveolar oxygen tension is 43-45 mmHg. Figure 2.3 is a graphical representation of the changes in alveolar gas tensions with altitude when breathing 100% oxygen, and should be compared with Figure 2.2.

The concept of physiologically equivalent altitudes for a man breathing air or 100% oxygen is of considerable value in the design of protective equipment. However, whilst equivalent altitudes may be stated in terms of equality of alveolar oxygen tension, a strict interpretation of the alveolar equivalence would require steady state conditions, the determination of the carbon dioxide tensions in both cases and knowledge of the value of the Respiratory Exchange Ratio. For most practical purposes, therefore, it is more satisfactory to determine equivalence on the basis of equality of inspired (tracheal) oxygen tension. Figure 2.4 describes the relationship of equivalent altitudes for both inspired gas and alveolar gas. As a simple example, the effect of the 5000 feet increase in altitude from 40000 to 45000 feet when breathing 100% oxygen is equivalent to a 9000 feet increase in altitude from 11000 to 20000 feet when breathing air.

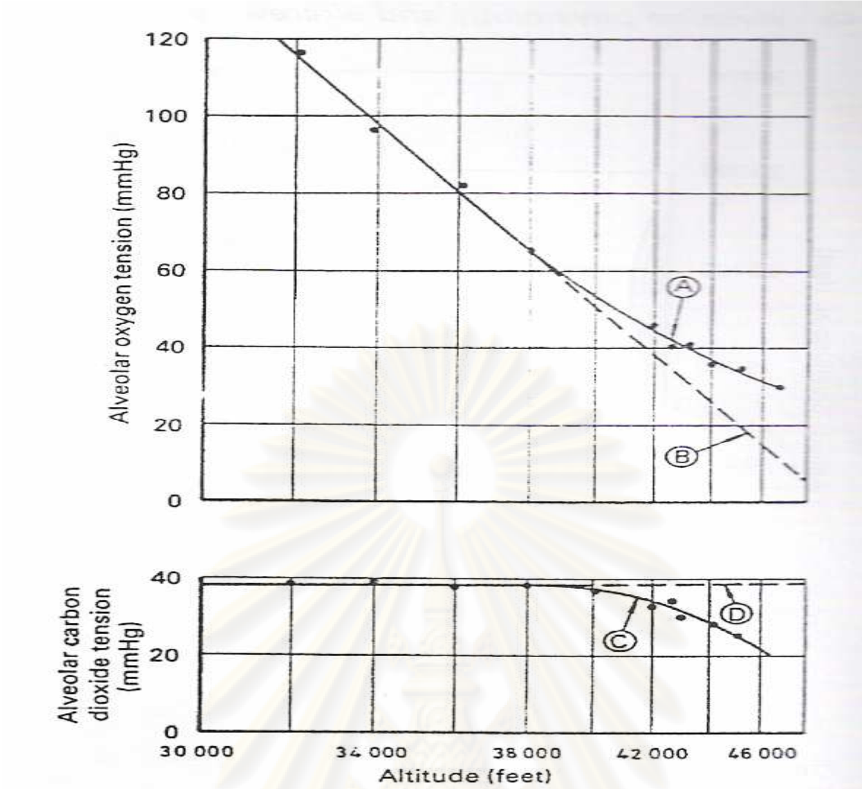
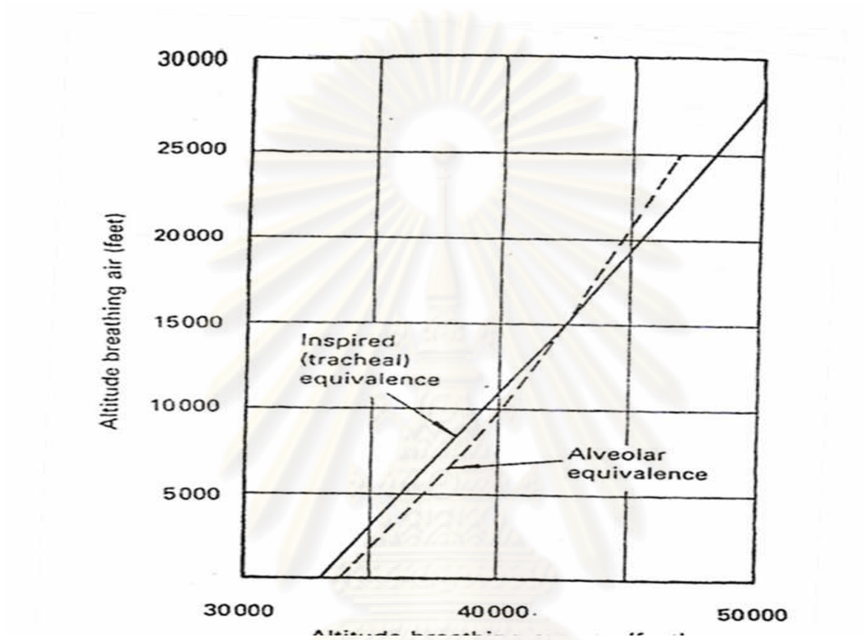


Figure 2.3 The effect of acute exposure to altitudes between 30000 feet and 45000 feet. (Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

whilst breathing 100% oxygen, on the alveolar tensions of oxygen (curve A) and carbon dioxide (curve C). The dashed lines indicate the values of alveolar tensions of oxygen (curve B) and carbon dioxide (curve D) which would have occurred in the absence of any increase in pulmonary ventilation.

Finally, when considering the alveolar gases when breathing oxygen it is important to consider the situation that can occur in practice as a result of a change from breathing oxygen to air at altitude, such as may occur as a result of a regulator failure or disconnection of an oxygen supply hose. In such circumstances the composition of the inspired gas changes from that containing a high concentration of oxygen to air and the alveolar oxygen tension falls progressively as the concentration of nitrogen in the inspired and alveolar gases rises to 79-80%. During the early part of this process the oxygen tension of the inspired gas is frequently less than the blood returning to the alveoli, and oxygen will pass out of the body from the returning mixed venous blood into the alveolar gas and the expiration. The rate at which alveolar oxygen tension falls in these circumstances is proportional to the alveolar ventilation, but a new steady state is usually attained in the resting subject two to three minutes after the reduction in concentration of oxygen in the inspired gas.



Altitude breathing oxygen (feet)

Figure 2.4 equivalent altitudes when breathing air and when breathing 100% oxygen. (Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

The solid curve indicates equivalence based on equal tensions of oxygen in the inspired (tracheal) gas: that is, inspired gas satured with water vapour at 37°C. the dashed curve indicates equivalence based on equal tensions of oxygen in the alveolar gas during acute exposures of seated resting subjects for 10-15 minutes.

Tissue Oxygen Tension

The minimum acceptable oxygen tension in a tissue depends critically on the oxygen tension in the blood flowing through its capillaries; and the major factor minimizing the fall of oxygen tension towards the venous ends of capillaries in the presence of hypoxic hypoxia is the relationship, reflected in the sigmoid shape of the oxygen dissociation curve, between oxygen tension and the saturation of haemoglobin with oxygen. A typical oxygen dissociation curve is shown in Figure 2.5.

The Figure 2.5 shows that, when air is breathed at sea level, which produces an arterial oxygen tension of about 95 mmHg, the extraction of 5 ml oxygen from every 100 ml blood flowing through the tissues results in a venous oxygen tension of about 40 mmHg, that is, a fall of 55 mmHg. The extraction of the same quantity of oxygen per unit volume of blood when the arterial oxygen tension is reduced to 32 mmHg by breathing air at 18000 feet, decreases the oxygen tension of the venous blood to 22 mmHg, thus the fall in oxygen tension as the blood flows through the tissues is reduced to only 10 mmHg. This most important protective effect of the manner in which oxygen combines with haemoglobin results in a halving of the arterio-venous oxygen tension difference when the arterial oxygen tension is reduced from 95 mmHg to 65 mmHg, and to a reduction to a quarter when the arterial oxygen tension is 40 mmHg. Although the overall increase in cardiac output produced by acute hypoxia reduces still further the fall in arterio-venous oxygen tension difference, this effect is less importance than that associated with the oxygen dissociation curve. For example, the 20% increase in cardiac output induced by breathing air at 18000 feet, where the arterial oxygen tension is 32 mmHg, will only raise the oxygen tension in mixed venous blood from 22 mmHg to 24 mmHg.

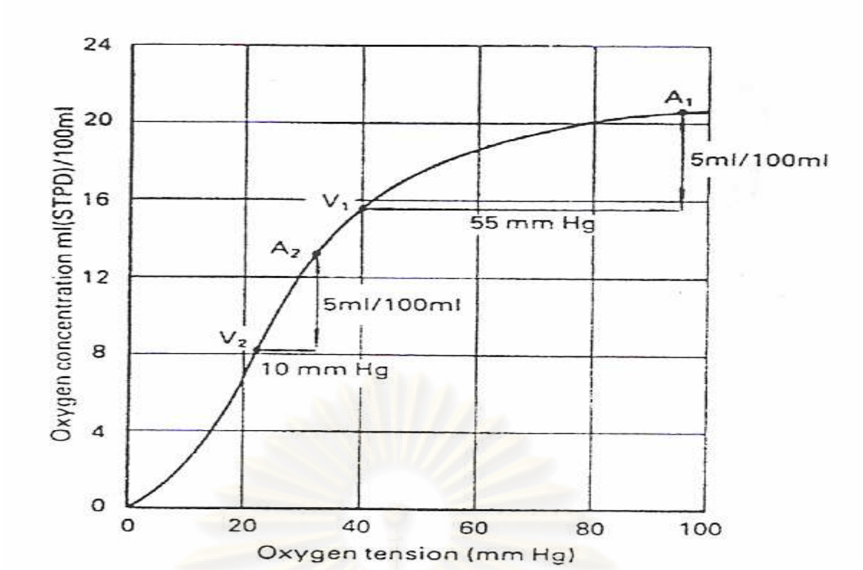


Figure 2.5 Oxygen dissociation curve of whole blood (at a pH of 7.4 and a temperature of 37°C) (Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

illustrating the effect of the sigmod shape of the relationship on the fall in oxygen tension of the blood produced by the extraction of 5 ml oxygen per 100 ml blood by the tissues, as blood flows through them at two different levels of arterial oxygen tension. At an arterial oxygen tension of 95 mmHg (point A_1), the extraction of 5 ml oxygen per 100 ml blood reduces the oxygen tension to 40 mmHg (point V_1); that is, the fall in oxygen tension from arterial to venous blood is 55 mmHg. In moderate hypoxia, with an arterial oxygen tension of 32 mmHg (point A_2), the extraction of the same amount of oxygen reduces the oxygen tension to 22 mmHg (point V_2); that is, the fall in oxygen tension from arterial to venous blood is only 10 mmHg.

Regional changes in blood flow, and especially the changes in the cerebral circulation described above, are also important. The marked reduction in cerebral blood flow, produced by the hypocapnia associated with the mild hypoxia induced by breathing air at 12000 feet, can result in an appreciable further lowering of the rugular venous oxygen tension. In the severe hypoxia associated with breathing air at 18000 feet, the increased arterio-venous oxygen tension difference produced by hypocapnia is more than offset by the concomitant increase in alveolar and arterial oxygen tensions produced by the hyperventilation.

The combined effects of acute hypobaric hypoxia and the associated hypocapnia arising from the hypoxic drive to ventilation, induced by a reduction in the oxygen tension of inspired gas, are summarized in the gradients of oxygen tension from the dry atmosphere to the lowest tension in the tissues. Figure 2.6 illustrates oxygen tension gradients for a man breathing air at sea level and at 18000feet. The figure shows three oxygen tension gradients at 18000 feet: the gradient for the body as a whole (assuming that all tissues are uniform), and two gradients for oxygen transport to the brain with mild and severe hypocapnia (alveolar carbon dioxide tensions of 35 and 20 mmHg, respectively) that would result from different degrees of increased alveolar ventilation. The curves illustrate the effect of hyperventilation upon the fall in oxygen tension between inspired and alveolar gases, and the marked reduction in the fall in oxygen tension along the capillaries in hypoxia due primarily to the relationship demonstrated by the shape of the oxygen dissociation curve. The net effect in this example in that, in the face of a reduction of 79 mmHg in the oxygen tension of the inspired gas, the oxygen tension of mixed venous blood is only reduced by 16 mmHg when air is breathed at 18000 feet. The estimated minimum oxygen tension, on the simplifying assumption that that the body is a single uniform tissue, is only reduced from 20 to 10 mmHg. In the absence of hyperventilation at 18000 feet, however, the minimum oxygen tension in the brain falls to almost zero, and some decline in oxidative phosphorylation would be expected under these conditions.

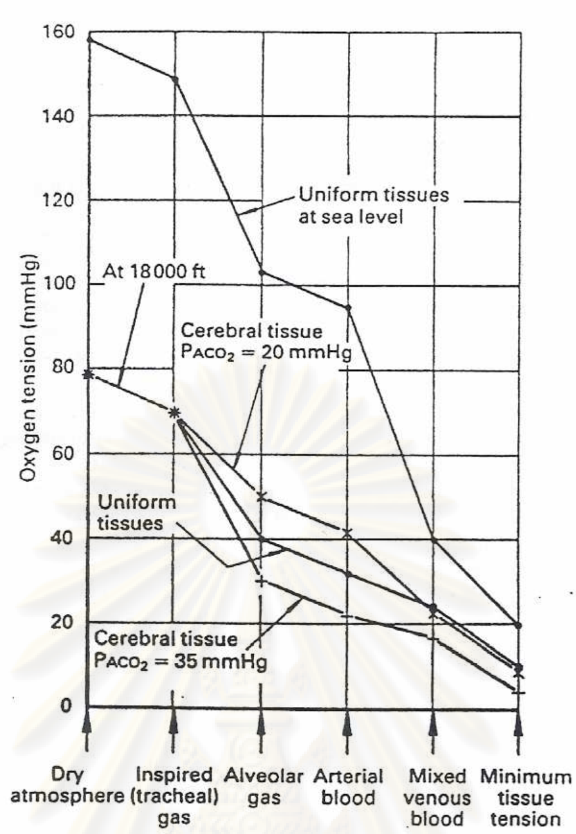


Figure 2.6 Oxygen tension gradients from dry atmosphere to minimum tissue level in an individual breathing air at sea level and at 18000 feet (curve O-O)

(Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

assuming that body tissues are uniform and that the alveolar carbon dioxide tension is 40 mmHg at sea level and 30 mmHg at 18000 feet. The gradients for cerebral tissue in an individual breathing air at 18000 feet with an alveolar oxygen tension of 20 mmHg (curve x-x) and 35 mmHg (curve +-+) are also shown.

Neurological Effects of Acute Hypobaric Hypoxia

Impairment of mental performance

The impairment of the psychological performance produced by the lack of oxygen at altitude is of the great practical significance in aviation, although there is a great variability within and between individuals exposed to the hypobaric hypoxia. Most of this variation is the result of differences in the respiratory response to hypoxia, with consequently very significant temporal and individual differences in the tensions of oxygen and carbon dioxide in the arterial blood when exposed to a given level of inspired oxygen tension. The hypocapnia induced by the low arterial oxygen tension affects mental performance by reducing still further cerebral tissue oxygen tension, as a consequence of the cerebral vasoconstriction is produced, and by increasing the pH of cerebral tissue.

Psychomotor tasks

Performance at well-learnt and practiced tasks is generally preserved adequately up to an altitude of at least 10000 feet but when alveolar oxygen falls to below 38-40 mmHg (that is, above an altitude of 16000-18000 feet), simple reaction time begins to be affected although even a reduction of the alveolar oxygen tension to 35 mmHg increases the simple reaction time by only 50% on average. Performance at pursuitmeter tasks is unaffected until the altitude exceeds 12000-14000 feet, although the decrement of performance at the type of task does not become severe until altitudes of 16000-17000 feet are exceeded. More demanding tasks, such as a choice-reaction time, is affected, however, by much less severe degrees of hypoxia, for example, performance at such a test is usually significantly impaired at 12000 feet. However, tasks requiring complex eye-hand coordination, such as instrument flying, which have been well learned in a flight simulator before the exposure, are usually unaffected until the alveolar oxygen tension is reduced below 55 mmHg (that is, until air is breathed at altitudes above 10000 feet). If the alveolar oxygen tension falls to less than 50 mmHg (12000 feet), there is an approximate 10% decrement in the ability to maintain a given air speed, heading or vertical velocity. This decrement rises to 20-30% at alveolar oxygen tensions of 40-45 mmHg (15000 feet).

Psychomotor performance is further compromised by the impairment of muscular coordination produced by moderate and severe hypoxia. Above 15000 feet, for example, a fine tremor of the hand develops so that the ability to hold a stylus or control lever in a fixed position in space is progressively impaired. Muscular incoordination becomes greater with increasing altitude and the subject's writing becomes hard to read.

Cognitive tasks

Performance at previously learned coding and conceptual reasoning tasks is unaffected at altitudes up to about 10000 feet; that is, for as long as the alveolar oxygen tension remains greater than 55 mmHg. At alveolar tensions less than this, however, performance declines slowly at first but then with increasing rapidity with increasing attitude. Thus the time taken to complete a simple coding task is increased by 10-15% at 15000 feet, and by 40-50% at 18000 feet. The decline in performance at conceptual reasoning tasks in even greater, although the altitude at which impairment of mental ability commences, and the severity of the decrement, varies with the difficulty and complexity of the task.

Short-term and long-term memory, as tested by paired word association, and immediate and delayed recall of patterns and positions, is significantly affected when the alveolar oxygen tension is reduced to about 60 mmHg (breathing air at 8000-10000 feet). Memory scores may be 25% lower than at sea level at an altitude of 15000 feet.

An individual breathing air at 8000 feet may take significantly longer to achieve optimum performance at novel tasks than is the case at sea level. For example, this degree of hypoxia has been found to double the reaction ties of initial responses to a complex choice-reaction task as compared with responses at sea level. The intensity of this effect increases with altitude and complexity of the task, markedly so above 12000 feet, and indeed the threshold for the detrimental effect of hypoxia on performance remains the subject of debate. Although it is recognized that there is very considerable individual variation in the threshold of effect a number of studies have concluded that such changes can be demonstrated at altitude as low as 5000-600 feet.

The mechanisms responsible for the cerebral effects of mild hypoxia are not understood, although it is likely that retardation of some oxygenation processes within the brain, leasing to disruption of neurotransmitter formation and decay, is involved rather than a failure of oxidative phosphorylation (see Chapter 4). This is because the oxygen tension of cerebral venous blood falls by only 2-4 mmHg on ascent from sea level to 8000 feet, and such a slight fall could not be responsible for the effects seen.

Impairment of the special senses

A subjective darkening of the visual field is a common symptom of hypoxia, although the individual may become aware of this only after the normal alveolar oxygen tension has been restored when there is a marked apparent increase in the level of illumination. Even very mild hypoxia, such as that produced by lowering the alveolar oxygen tension to 75 mmHg (that is, equivalent to breathing air at just 5000 feet), can be shown in the laboratory to impair the light sensitivity of the dark-adapted eye (scotopic or rod vision). The magnitude of the effect, however, is of little practical importance in aviation. The degree of reduction in light sensitivity of scotopic vision only becomes significant when the alveolar oxygen tension falls below about 50 mmHg, that is, when air is breathed at altitudes above 12000 feet. Retinal sensitivity in relatively bright light (photopic or cone vision) is unaffected by hypoxia until the alveolar oxygen tension is reduced below 40 mmHg. Finally, moderate and severe hypoxia cause restriction of the visual field, with loss of peripheral vision ("tunneling") and the development of a central scotoma.

Auditory acuity is also reduced by moderate and severe hypoxia, but some hearing is usually retained even after the other special senses have been lost. The effect of hypoxia on directional hearing remais under investigation and may have operational significance to the use of warning tones with a directional component given to a pilot through his headset.

Loss of consciousness

Although the arterial oxygen tension in the cerebral tissue is of crucial importance to an individual's degree of consciousness, its effects is subject to considerable modification as a result of other influences, such as cerebral blood flow and the degree of hypocapnia present. It has been found that a much closer correlation exists between the oxygen tension of jugular venous blood and the level of consciousness under conditions of hypoxic hypoxia, provided that vasovagal syncope does not supervene. Consciousness is lost when the jugular not supervene. Consciousness is lost when the jugular venous oxygen tension (see Figure 5.6) is reduced to 17-19 mmHg. Unconsciousness may therefore occur with arterial oxygen tension between 20 and 35 mmHg, depending on the degree of hypocapnia. Accordingly, although consciousness is usually lost when the alveolar oxygen tension is reduced to 30 mmHg or below for a significantperiod of time, it is possible to lose consciousness with an alveolar oxygen tension as high as 40 mmHg if there is marked hyperventilation, or to retain consciousness, at least for a time, at an alveolar oxygen tension as low as 25 mmHg if there is no hypocapnia. A subject breathing air an acute exposure to altitude may therefore become unconscious at an altitude as low as 16,000 feet or stay conscious for some minute as high as 24000 feet.

Clinical Features of Acute Hypobaric Hypoxia

The clinical picture of acute hypobaric hypoxia in a combination of the cardio-respiratory responses and neurological effects described above, and the symptoms and signs are consequently extremely variable. The speed and order of appearance of signs, and of the severity of symptoms produced by a lowering of inspired oxygen tension, depend on the rate and degree to which the tension is lowered, and on the duration of exposure to hypoxia. Even when these factors are kept constant, however, there is considerable variation between on individual and another in the effects of hypoxia; although for the same individual the pattern of effects does tend to follow the same trend from one occasion to another.

The factors that may influence an individual's pattern of symptoms and signs produced by hypoxia and their personal susceptibility are:

1. The intensity of hypoxia – The maximum altitude, the rate of ascent and the duration of exposure to altitude
2. Physical activity – Exercise exacerbates the features of hypoxia.
3. Ambient temperature – A cold environment will reduce tolerance to hypoxia, in part at least, by increasing metabolic workload.
4. Intercurrent illness – Similarly, the additional metabolic load imposed by ill health will increase susceptibility to hypoxia.
5. Ingestion of certain drugs, including alcohol – Many pharmacologically active substances have effects similar to those of hypoxic hypoxia and so mimic or exacerbate the condition. Those proprietary preparations with anti-histamine constituents are particularly likely to cause problem, as is alcohol.

The Incidents of Hypoxic Hpoxia in the Variable Altitudes

1.Up to 10000 feet Breathing Air (up to about 39000 feet breathing oxygen)

The normal resting subject has so symptoms on ascent to an altitude of 10,000 feet when breathing air, or 39,000 feet when breathing 100% oxygen, but performance at novel tasks will be impaired.

2.From 10,000 to 15,000 feet Breathing Air (from about 39,000 to 42,500 feet breathing oxygen)

A warm, resting subject exhibits few or no signs and has virtually no symptoms. The ability to perform skilled tasks is impaired, however: an effect of which the subject is frequently unaware. A prolonged exposure to the moderate hypoxia at about 15000 feet frequently causes a severe generalized headache. Physical work capacity is markedly reduced, and exposure to extremes of temperature may induce symptoms and signs of hypoxia.

3.From 15,000 to 20,000 feet Breathing Air (from about 42,500 to 45,000 feet breathing oxygen)

Even in the resting subject, the symptoms and signs of hypoxia appear on acute exposure to altitude greater than 15,000 feet when breathing air. Higher mental processes and neuromuscular control are affected, and in particular there is a loss of critical judgement and willpower. Because of the loss of self-criticism, the subject is usually unaware of any deterioration in performance or indeed of the presence of hypoxia; and it is this effect that makes the condition such a potentially dangerous hazard in aviation. Thought processes are slowed, mental calculations become unreliable, and psychomotor performance is grossly impaired. Marked changes in emotional state are common. Thus there may be disinhibition of basic personality traits and emotions, and the individual may become elated or euphoric or pugnacious and morose. Occasionally the vitim may become physically violent. Tunneling of vision may occur.

In parallel with this group of cerebral features, disturbances due to hypocapnia commonly occur, and indeed may dominate the clinical picture, as hyperventilation occurs. Lightheadedness, visual disturbances, and paraesthesiae of the extremities and lips may be followed in severe causes by tetany with carpopedal and facial spasms. Central and peripheral cyanosis develop, and there is decreased muscular coordination with loss of the sense of touch, so that delicate or fine movements are impossible.

Physical exertion greatly increases the severity and speed of onset of all of these symptoms and signs, and may lead to unconsciousness.

4.Above 20,000 feet Breathing Air (above about 45,000 feet breathing oxygen)

Resting subjects exhibit a marked accentuation of the symptoms and signs described above. Comprehension and mental performance decline rapidly, and unconsciousness supervenes with little or no warning. Myoclonic jerks of the upper limbs often precede loss of consciousness, and convulsions may occur thereafter. Hypoxic convulsions are characterized by intense, maintained muscular contractions which produce opisthotonos, preceded or followed by one or more myoclonic jerks.

The early (covert) cerebral features of hypobaric hypoxia may be summarized as follows:

1. Visual function:

(a) Light intensity perceived as reduced.

(b) Visual acuity diminished in poor illumination.

(c) Light threshould increased.

(d) Peripheral vision narrowed.

2. Psychomotor function:

(a) Learning novel tasks impaired.

(b) Choice reaction time impaired.

(c) Eye-hand coordination impaired.

3. Cognitive function:

(a) Memory impaired.

The covert features of acute hypobaric hypoxia may be summarized as follows:

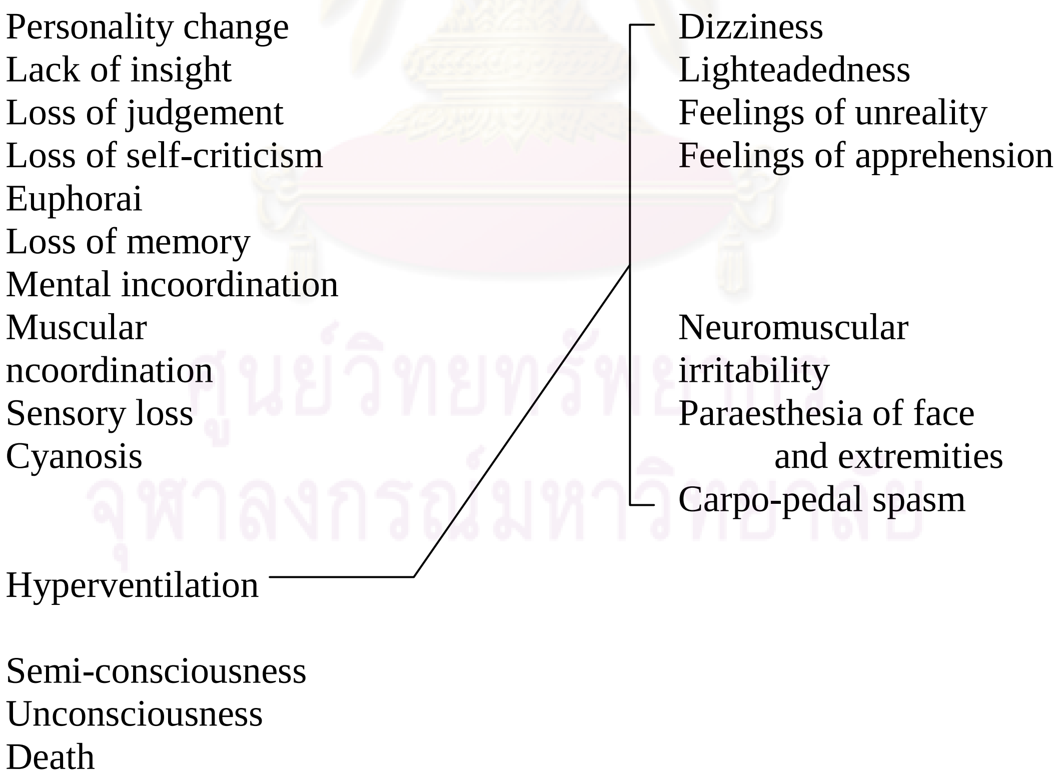


Figure 2.7 The summary of the acute hypobaric hypoxia

(Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

Time of useful consciousness (TUC)

The interval that elapses between a reduction in oxygen tension of the inspired gas and the point at which there is a specified degree of impairment of performance is termed “the time of useful consciousness” (TUC). The length of this interval is influenced by many factors, of which the most important is the accepted degree of impairment. In the laboratory, this may vary from an inability to perform complex psychomotor tasks to a failure to respond to simple spoken commands. In practice, however, the most useful concept is to regard the time of useful consciousness as the period during which the affected individual can act to correct his predicament.

Values for the time of useful consciousness at various altitude following hypoxia induced by changing the breathing gas from oxygen to air are presented in Table 2.3. The large standard deviations at low altitudes serve to emphasize the considerable individual variation in the time of useful consciousness. The variation is a reflection of the influence of many factors including the pulmonary ventilatory response to hypoxia, the general physical fitness of the subject, age, degree of training, and previous experiences of hypoxia. It should be noted that the time of useful consciousness at a given altitude is shorter when hypoxia is induced by rapid decompression, rather than by slow ascent.

Consideration of the time of useful consciousness when breathing 100% oxygen, rather than air, is aided by the concept of equivalence of altitude, as previously described. This suggests that an individual breathing 100% oxygen at 42000 feet would be at an alveolar equivalent of breathing air at 16000 feet, but, however, at higher altitudes than this tracheal values tend to over-estimate actual alveolar conditions with TUCs considerably less than might be predicted from simple equivalence

Table 2.3 Times of useful consciousness at various altitudes of 50 seated young men following a change from breathing oxygen to breathing air (Ernsting J, Nicholson AN and Rainford DJ. Aviation Medicine, 1999)

Altitude (ft)	Time of Useful Consciousness (seconds)	
	Mean	Standard Deviation
25,000	270	96
26,000	220	87
27,000	201	49
28,000	181	47
30,000	145	45
32,000	106	23
34,000	84	17
36,000	71	16

Recovery from hypoxia and the oxygen paradox

The administration of oxygen to a hypoxic subject usually results in a rapid and complete recovery; as is also the case if environmental pressure is increased so that alveolar oxygen tension is restored towards its normal level. A generalized headache is the only symptom that persists, and only then if the exposure to hypoxia was prolonged.

In some subjects, however, sudden restoration of the alveolar oxygen tension to normal may cause a transient (paradoxical) worsening of the severity of the symptoms and signs of hypoxia for 15-60 seconds. This oxygen paradox is usually mild and is manifest only by flushing of the face and hands and perhaps a deterioration in performance of complex tasks over the immediate period following restoration of the oxygen supply. Occasionally, oxygen administration may produce a severe paradox with the appearance of chronic spasms and even loss of consciousness. The mechanisms responsible for the phenomenon are uncertain.

The paradox usually occurs in subjects who have become hypocapnic during hypoxia, and it is also accompanied by a period of arterial hypotension. It may be that there is a significant reduction in peripheral resistance on the restoration of a normal arterial oxygen tension and this induces a generalized fall in blood pressure. This hypotension, in combination with persistent and marked hypocapnia, may result in cerebral hypoperfusion and vasoconstriction which persists for some while after the restoration of the arterial tension, and may intensify cerebral hypoxia for a short time. Clearly, it is important that oxygen continues to be delivered to the victim of a paradox, despite the apparent worsening of the condition on initial administration of the gas.

Hyperventilation

Hyperventilation is a condition in which pulmonary ventilation is greater than that required to eliminate the carbon dioxide produced by the tissue. The consequent excessive removal of carbon dioxide from the alveolar gas, the arterial blood and the tissues results in a reduction in the tension of carbon dioxide throughout the pathway.

Furthermore, there is a close relationship between carbon dioxide tension and hydrogen ion concentration in the blood and tissues since these substances are in equilibrium according to the equation:

$$CO_2 + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$$

A reduction in carbon dioxide tension will drive the equilibrium towards the left and consequently there is a fall in hydrogen ion concentration; that is, a rise in pH. Thus hyperventilation also causes an increase in the pH of blood and tissues; that is a respiratory alkalosis.

Aetiology

As described above, hyperventilation is a normal response to hypoxia and is seen when alveolar oxygen tension is reduced to below 55-60 mmHg. It may also occur as a result of voluntary over-breathing: for example, in preparation for a breath-hold dive into water.

More commonly, however, the condition is produced by emotional stress, particularly anxiely, apprehension or fear. Thus a significant proportion of student pilots under instruction exhibit gross hyperventilation in flight: indeed it has been claimed that 20-40% of student aircrew suffer from hyperventilation at some stage during flying training. The condition is also seen in experienced aircrew when, for example, they are exposed to the mental stress of a sudden in-flight emergency or when they are being trained to operate a new aircraft type. Aircraft passengers who are afraid or anxious frequently hyperventilate.

Pain sometimes induces hyperventilation, as do motion sickness and certain environmental stresses such as high ambient temperature and whole-body vibration at 4-8 Hz as, for example, produced by clear air turbulence when flying at low level. Finally, hyperventilation is almost invariable in aircrew during pressure breathing, and while this tendency may be reduced by training, it cannot be eliminated entirely.

Physiological Features of Hyperventilation

The hypocapnia of hyperventilation has no significant effect on cardiac output or arterial blood pressure although there is a redistribution of the former. Thus hypocapnia induces a marked vasoconstriction of the cerebral arterial and the vessels of the skin, whilst blood flow through skeletal muscle is increased. Although the intense cerebral vasoconstriction tends to minimize the change in hydrogen ion concentration within cerebral tissues, it also markedly reduces the minimum tissue oxygen tension. It is therefore probable that many of the changes produced by gross hyperventilation, and especially the deterioration in performance, the appearance of slow wave activity in the electroencephalogram, and the loss of consciousness are due to a combination of hypoxia and alkalosis in the cerebral tissues.

A reduction in the arterial carbon dioxide tension to below 25 mmHg causes a significant decrement in the performance of psychomotor tasks, such as tracking and complex coordination tests. The reaction time at a two-choice task is increased by about 10% by such a fall, and is increased by 15% at an arterial carbon dioxide tension of 15 mmHg. The ability to perform complex mental tasks, such as mental arithmetic, is compromised by a reduction in carbon dioxide tension to below 25-30 mmHg. Steadiness of the hands is also impaired by a reduction in arterial in arterial carbon dioxide tension to 25 mmHg. The ability to perform manual tasks is markedly affected by the muscle spasm which occurs at arterial carbon dioxide tension below 20 mmHg. Reduction of carbon dioxide tension below 10-15 mmHg produces gross clouding of consciousness and then unconsciousness.

The rise in tissue pH induced by hyperventilation increases the sensitivity of peripheral nerve fibres, and reduces the threshold for their response to stimuli. The threshold is lowered by the local fall in hydrogen ion concentration and spontaneous activity occurs giving rise to sensory disturbances, such as paraesthesiae in the face and extremities, and motor disruption, in the form of reflex firing of proprioceptive fibres via the spinal cord, causing muscle spasm (tetany). Different types of nerve fibres are affected in a consistent sequence: fibres conveying information with regard to touch, position, pressure and vibration being affected first, followed by motor fibres and then cold, heat and, lastly, pain fibres.

Clinical Features of Hyperventilation

The earliest symptoms produced by hyperventilation become manifest when the arterial carbon dioxide tension has been reduced to 20—25 mmHg. Usually, there are feelings of light-headedness, dizziness, anxiety which, since apprehension is itself a cause of hyperventilation, frequently establishes a vicious circle, and a superficial tingling (paraesthesiae) in the extremities and around the lips. The paraesthesiae are follow by muscle spasms, particularly of the limbs and of the face, when arterial carbon dioxide tension has fallen below 15-20 mmHg. Contracting of muscle groups in the wrist and hand, and in the ankle and foot, give rise to carpo-pedal spasm. In this state, the thumb is acutely flexed at the wrist, the metacarpo-phalangeal joints flexed and the inter-phalangeal joints are extended (the main d'accoucheur). The ankle is profoundly plantar flexed. Spasm of the facial muscles causes stiffening of the face and the corners of the mouth are drawn downwards (the risus sardonicus). In more severe hypocapnia, when arterial carbon dioxide tension is less than 15 mmHg, the whole body becomes stiff as a result of general tonic contractions of skeletal muscle (tetany).

The increased irritability of nervous tissue in moderate hypocapnia causes augmentation of tendon reflexes. An example of this lowered threshold can be demonstrated by tapping the branches of the facial nerve as they pass forward over the mandible: such tapping, in the presence of moderate alkalosis, causes twitching of the facial muscles (chvostek's sign). Finally, as described above, moderate and severe hyperventilation produce a general deterioration in mental and physical performance and this is followed by impairment of consciousness and finally unconsciousness.

It is most important to realize that, in the uncommon event of an individual hyperventilating to the point of unconsciousness as a result of aniety the supervention of coma will be followed by a gradual recovery as respiration is inhibited and carbon dioxide tension regain their normal levels. This is clearly not the case , however, if the hyperventilation has been induced by hypoxia. It will be apparent from the previous sections of this chapter that most of the early sumptoms of hypoxia are very similar to those produced by hypocapnia. Indeed, the light-headedness, paraesthesiae, and apprehension seen during acute hypoxia in a subject breathing air at altitudes between 15000 feet and about 20000 feet are due to the concomitant hypocapnia. Thus should always be suspected when symptoms or signs of hypocapnia occur at altitude above about 12000 feet, and the corrective procedures must be based on the assumption that the condition is caused by hypoxia until proved otherwise.

Hypoxic Ventilatory Response (HVR)

S. Grant et al. (2002) stated that a strong hypoxic ventilatory response (HVR) is considered by some to be advantageous for climbers at high altitude, resulting in an increased arterial oxygen saturation (SaO_2) allowing people to attain greater altitudes than those with a lower HVR. In the fact that native altitude dwellers have a blunted ventilatory response, but appear to be less susceptible to AMS than low level residents. Ventilatory acclimatization to hypoxia in a mountain environment requires many days and is characterised by the individual variability. If it were possible to predict the ventilatory acclimatization response before a sojourn to the mountains, subjects who respond poorly to an hypoxic environment could be identified and precautions taken to avoid problems at altitude.

N.E. Townsend et al. (2002) researched that the ventilatory acclimatization to altitude is facilitated by the increased sensitivity of the peripheral chemoreceptors to hypoxia, estimated by the hypoxic ventilatory response (HVR) in humans. The HVR has been reported to correlate with the magnitude of increase in $\dot{V}_E$ on arrival at altitude, and several studies have demonstrated an increase in the HVR during natural altitude acclimatization or intermittent hypoxic exposure. An enhancement of the HVR during acclimatization is viewed as a positive adaptation, because an increase in $\dot{V}_E$ improves alveolar O_2 pressure and raises arterial oxygenation while at altitude. An increase in the HVR allows ventilatory acclimatization to altitude to proceed, despite an inhibitory influence of respiratory alkalosis and a decrease in the original hypoxic stimulus. In contrast to altitude acclimatization, endurance training appears to decrease the HVR. Endurance trained athletes demonstrate a blunted HVR compared with untrained, healthy individuals, and a decrease in the HVR has been observed after endurance training in previously untrained subjects.

Hypobaric Hypoxic Training Program

Millet GP. et al. (2010) stated that New methods and devices for pursuing performance enhancement through altitude training were developed in Scandinavia and the USA in the early 1990s. The variety types of the hypobaric hypoxic training program were invented. There were designed into 5 patterns in this decade ;

1) The traditional program - Live high-Train high (LHTH)
2) The contemporary program - Live high-Train low (LHTL)
3) The intermittent hypoxic exposure during rest program (IHE)
4) The intermittent hypoxic exposure during continuous session program (IHT)
5) The new combination of the different hypoxic training methods

The proper number of sessions for the hypoxic training program in the sojorns was at least 1 week and more. The optimal duration was 1 hour per session per day. Many studies showed the insignificant differences between the short, long and intermittent durations of the hypoxic training programs (Hector C. et al.; 2000, Katayama K. et al, 2002; Katayama K. et al, 2009).

Prevention of Altitude Illnesses

Prevention of altitude illnesses falls into two categories, the proper acclimatization and the preventive medications. Below are a few basic guidelines for the proper acclimatization.

- If possible, don't fly or drive to high altitude. Start below 10,000 feet (3,048 meters) and walk up.
- If you do fly or drive, do not over-exert yourself or move higher for the first 24 hours.
- If you go above 10,000 feet (3,048 meters), only increase your altitude by 1,000 feet (305 meters) per day and for every 3,000 feet (915 meters) of elevation gained, take a rest day.

- "Climb High and sleep low." This is the maxim used by climbers. You can climb more than 1,000 feet (305
- meters) in a day as long as you come back down and sleep at a lower altitude.
- If you begin to show symptoms of moderate altitude illness, don't go higher until symptoms decrease ("Don't go up until symptoms go down").
- If symptoms increase, go down, down, down!
- Keep in mind that different people will acclimatize at different rates. Make sure all of your party is properly acclimatized before going higher.
- Stay properly hydrated. Acclimatization is often accompanied by fluid loss, so you need to drink lots of fluids to remain properly hydrated (at least 3-4 quarts per day). Urine output should be copious and clear.
- Take it easy; don't over-exert yourself when you first get up to altitude. Light activity during the day is better than sleeping because respiration decreases during sleep, exacerbating the symptoms.
- Avoid tobacco and alcohol and other depressant drugs including, barbiturates, tranquilizers, and sleeping pills. These depressants further decrease the respiratory drive during sleep resulting in a worsening of the symptoms.
- Eat a high carbohydrate diet (more than 70% of your calories from carbohydrates) while at altitude.
- The acclimatization process is inhibited by dehydration, over-exertion, and alcohol and other depressant drugs.

Preventive Medications

1. **Diamox** (Acetazolamide) allows you to breathe faster so that you metabolize more oxygen, thereby minimizing the symptoms caused by poor oxygenation. This is especially helpful at night when respiratory drive is decreased. Since it takes a while for Diamox to have an effect, it is advisable to start taking it 24 hours before you go to altitude and continue for at least five days at higher altitude. The recommendation of the Himalayan Rescue Association Medical Clinic is 125 mg. twice a day (morning and night). (The standard dose was 250 mg., but their research showed no difference for most people with the lower dose, although some individuals may need 250 mg.) Possible side effects include tingling of the lips and finger tips, blurring of vision, and alteration of taste. These side effects may be reduced with the 125 mg. dose. Side effects subside when the drug is stopped. Contact your physician for a prescription. Since Diamox is a sulfonamide drug, people who are allergic to sulfa drugs should not take Diamox. Diamox has also been known to cause severe allergic reactions to people with no previous history of Diamox or sulfa allergies. Frank Hubbell of SOLO recommends a trial course of the drug before going to a remote location where a severe allergic reaction could prove difficult to treat.

2. **Dexamethasone** (a steroid) is a prescription drug that decreases brain and other swelling reversing the effects of AMS. Dosage is typically 4 mg twice a day for a few days starting with the ascent. This prevents most symptoms of altitude illness. It should be used with caution and only on the advice of a physician because of possible serious side effects. It may be combined with Diamox. No other medications have been proven valuable for preventing AMS.

3. **Other Medications for Altitude Illnesses**

Ibuprofen is effective at relieving altitude headache. Nifedipine rapidly decreases pulmonary artery pressure and relieves HAPE. Breathing oxygen reduces the effects of altitude illnesses.

4. **Gamow Bag (pronounced ga´ mäf)**

This clever invention has revolutionized field treatment of high altitude illnesses. The bag is basically a sealed chamber with a pump. The person is placed inside the bag and it is inflated. Pumping the bag full of air effectively increases the concentration of oxygen molecules and therefore simulates a descent to lower altitude. In as little as 10 minutes the bag can create an “atmosphere” that corresponds to that at 3,000 - 5,000 feet (915 - 1,525 meters) lower. After a 1-2 hours in the bag, the person’s body chemistry will have “reset” to the lower altitude. This lasts for up to 12 hours outside of the bag which should be enough time to walk them down to a lower altitude and allow for further acclimatization. The bag and pump weigh about 14 pounds (6.3 kilos) and are now carried on most major high altitude expeditions. Bags can be rented for short term trips such as treks or expeditions.

CHAPTER III

RESEARCH METHODOLOGY

Research Design

This study is an experimental study to examine the effect of the hypobaric hypoxic training on hypoxic ventilatory response in Thai military airborne. The experimental protocal was approved by the Chulalongkorn University Ethics Committee, Faculty of Medicine. All volunteers gave their informed consent before taking part in this study.

Target and Sample Populations

1. Target population

The target populations were defined as all personnel who are positioned and/or operated in the Military Airborne unit, the Military Special Forces unit, all type of Airmen, and the associated fields.

2. Study Population

The study population were the airborne troopers who positioned in the airborne operation unit of Royal Thai Air Force such as the commandoes, pararescuemen, airborne companies. They have to pass the airborne qualification.

3. Sample

Thai healthy airmen who represent as the healthy military airborne personnel. They were recruited from the Royal Thai Air Force Special Operations Regiment. All subjects passed the qualification of the standard military airborne that they are matched with the inclusive criteria.

Eligibility Criteria

Inclusion Criteria

1. Healthy males aged 21 – 38 years, who are positioned and/or operated in the Thai military airborne duties.
2. All volunteers have passed the Aviation Medical Examinations of the Institute of Aviation Medicine, Royal Thai Air Force.
3. Subjects are free of the medical and physical conditions which interfere the airborne operations and the physical tests.
4. They are no history of the cardiovascular and respiratory diseases.
5. No medical treatments which affect the cardiovascular system have taken during this study.
6. All subjects do not have the blood pressure exceeded than 140/90 mmHg.
7. They accepted to inform the consent.

Exclusion Criteria

1. Subjects who would seriously injured or get sick during the training sessions and could not continue the training program.
2. Volunteers who cannot participate in the hypobaric hypoxic training program continuously.
3. Tests were not completed.

Sample Size

To determine the sample size in this study, the researcher used the previous study, Keisho Katayama (2002), which measured the hypoxic ventilatory response in healthy male population. They were eight (0.71 ± 0.2 L/min/%) and six (0.47 ± 0.15 L/min/%) men in the experimental and control groups respectively. The two independent groups formular was used for calculating the sample size.

$$n/group = 2(Z_{\alpha/2} + Z_{\beta})^2 \sigma^2 / (\bar{x}_1 - \bar{x}_2)^2$$

$$\sigma^2 = \frac{(n_1-1) S_1^2 + (n_2-1) S_2^2}{n_1+n_2-2}$$

α = 0.05

β = 0.10

$Z_{\alpha/2} = z_{0.05/2} = 1.96$ (two tail)

$Z_{\beta} = z_{0.10} = 1.28$

$\bar{X}_1$ = The averaged value of Hypoxic Ventilatory Response in the hypobaric hypoxic training group is 0.71 L/min/%

$\bar{X}_2$ = The averaged value of Hypoxic Ventilatory Response in the untrained group is 0.47 L/min/%

σ^2 = Pooled variance

$$= \frac{(n_1 - 1) S_1^2 + (n_2 - 1) S_2^2}{n_1 + n_2 - 2}$$

= 0.0351

$$n/group = 2(1.96 + 1.28)^2 (0.0351) / (0.71-0.47)^2$$

= 12.79

= 13 subjects

The result of this sample sized calculation is 13 subjects.

Sampling Method

The purposive sampling technique, non-probability sampling and voluntariness were used for recruiting subjects in this study.

Total 28 airborne troopers of the Royal Thai Air Force Special Operations Regiment were divided into two groups as the trained (N=13) and untrained (N=15) groups. The trained group was trained consecutively fourteen sessions in the hypobaric chamber. The standard group of Thai military airborne as the untrained or control group. All subjects passed the qualification of the standard military airborne troopers and were in the inclusive criteria.

Materials and Equipments

1. Digital weight scales (Tanita HD-314, USA)
2. Height measuring scale
3. Sphygmomanometer
4. Stethoscope
5. Skinfold caliper (CRE100 Lange Skinfold Caliper)
6. Oxygen and carbondioxide gas analyzer (CO_2 and O_2 Gas Analysis System for MP, MP100WS, Biopac Systems,INC.)
7. Hypobaric chamber (12/4 Model, ETC, USA)
8. Portable Oximeter (BCI 3301, Smiths Medical PM.INC.,USA)
9. Aviation helmet (RTAF, Thailand)
10. Aviation oxygen mask (MBU 5/D,12/D)
11. Stop watch (Casio,HS-3, China)
12. Form Fitter children toys (Playskool, USA)
13. 99.999% Nitrogen gas (Gas Center 2001 Limited Partnership,Thailand)
14. 100% Oxygen gas (Gas Center 2001 Limited Partnership,Thailand)
15. Cotton
16. 70% Alcohol
17. Case recorded forms

Measurements

The Pre-tested and Post-tested Measurements

The Fundamental Physical Characteristics Measurements

- Age (years ; yr.)
- Weight (killograms ; kg.)
- Height (centimeters ; cm.)
- Percentage of skinfold body fat (percentage ; %)
- Resting heart rate (beat per minute ; bpm)
- Blood pressure (mmHg)
- Resting respiratory rate (time per minute)

All the methods of the fundamental physical characteristic measurements followed the standard methodology of physical fitness measurements of the Sports Authority of Thailand (SAT).

Hypoxic Ventilatory Response Measurement

Parameters

- Resting respiratory rate (time per minute)
- Expired minute ventilation (V_I) (Liter per minute ; L/min)
- Expired O_2 and CO_2 Volume (Liter per minute ; L/min)
- Percentage of arterial oxygen saturation (percentage ; $\%SaO_2$)

Methods

1. To let subjects sit on a chair about 5-10 minutes before starting this test for decreasing their resting heart rate to be normal level.
2. Fitting and wearing the one-way non-rebreathing valved respiratory mask.
3. The Biopac system was applied.
4. For starting this measurement, subjects were control to breath at the nomal room air about 5 minutes for recording the resting respiratory rate.

5. To add the 99.999% of Nitrogen gas in the respiratory cycle on the respiratory mask with 2 L/min of the flow rate of Nitrogen gas and increase 1 L/min in every 30 seconds for 5 minutes until the percentage of the arterial oxygen saturation (%SaO_2) falling gradually to 75%SaO_2 and the concentration of oxygen in expired gas was 5% (38 mmHg).
6. To keep mornitoring the SaO_2 was 78% during this test for 2-3 minutes to collect the expired gas.
7. Cutting the Nitrogen gas off the respiratory cycle on the respiratory mask and observing the %SaO_2 to return to be at 97-99%.
8. Recording all data and taking the respiratory mask off.
9. Ventilatory data were accumulated on a breath-by-breath basis. The last minute of rest was used to calculate the resting ventilatory values.
10. Ventilation was plotted against the arterial oxygen saturation. The absolute value of the slope was taken as the hypoxic ventilatory response.
11. The *x*-axis (saturation) is plotted from right to left with 100% saturation on the left by convention to display a positive slope.
12. The HVR was plotted by the averaged value of expired gas volume per minute and the arterial oxygen saturation and the unit is L/min/%.

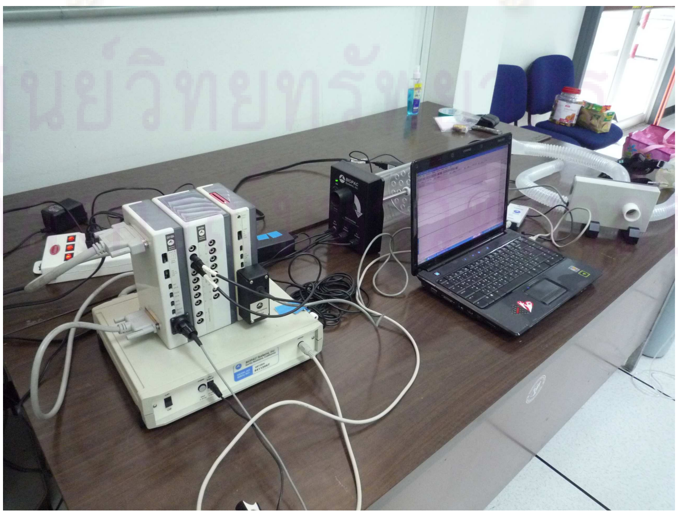


Figure 3.1 Gas Analyzer for Hypoxic Ventilatory Response Measurement

Figure 3.2 Fitting a one-way valved mask of Gas Analyzer

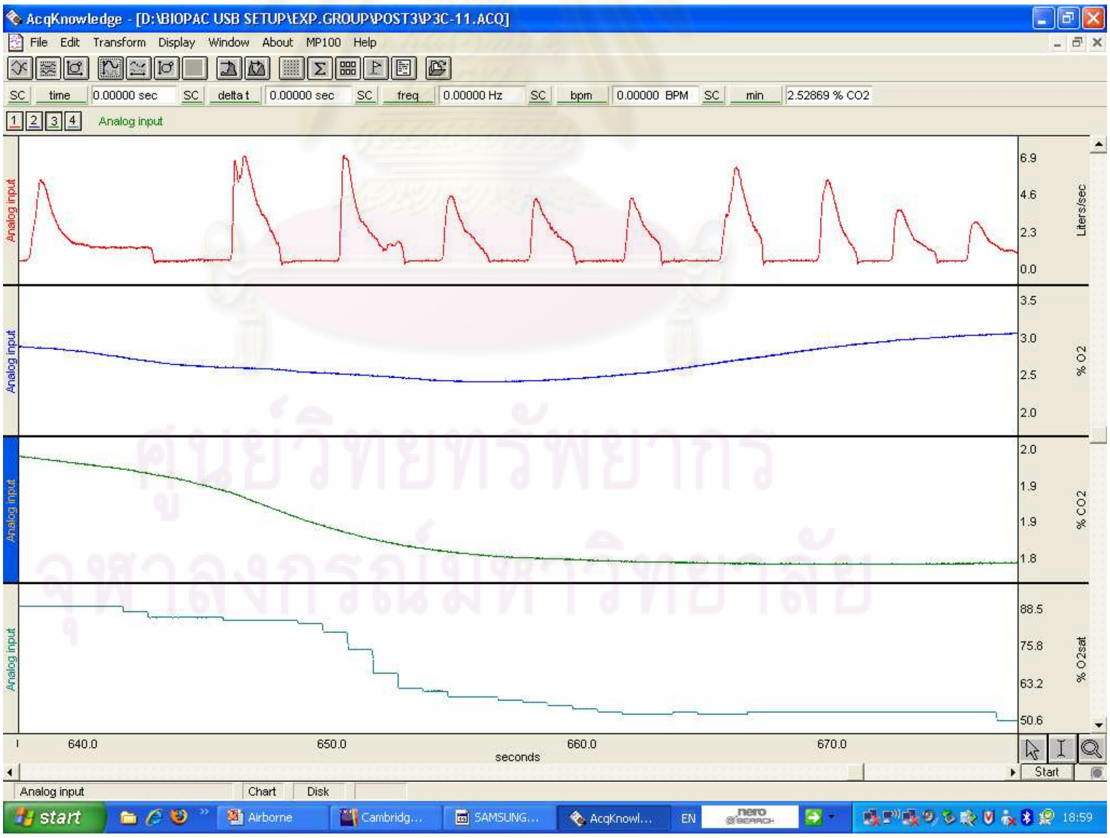


Figure 3.3 Sample of Hypoxic Ventilatory Response Measurement by Gas Analyzer

The Time of Useful Consciousness Measurement

Parameter : The duration of time of useful consciousness (minutes)

Methods

1. The training profile type VII of the simulating hypoxic hypoxia of the Institute of Aviation Medicine, Royal Thai Air Force was utilized in this project.
2. To do the pre-flight briefing lasts 30 minutes before testing by the aviation medicine instructor of the Institute of Aviation Medicine, Royal Thai Air Force.
3. Dividing twenty-eight subjects into three groups (flights) for the test in the hypobaric chamber which the first 2 flights were 10 subjects per flight and the last flight was 8 subjects.
4. Fitting and checking the avialable individual aviation oxygen masks and helmets for participants.
5. Arranging subjects to sit on the seats by following the personal numbers.
6. Giving the form fitter children toys to 5 subjects and laying the toys down on thier lap.
7. Running the hypobaric chamber with the climbing rate is 300 feet/min to the initial altitude, 3,000 feet MSL, lasting 5 minutes for clearing the trap gas in their body and rechecking the readiness to continue.
8. The chamber supervisor ordered all participants to wear the aviation oxygen masks completely at 10,000 feet MSL.
9. To climb gradually the altitude to 25,000 feet MSL with the climbing rate is 300 feet/min.
10. When reached the target altitude for this test, 25,000 feet MSL, the chamber supervisor orderded the first 5 subjects to do the coordinated exercise test by doing a form fitter children toy. The individual testing time had recorded immediately in minute after subjects unlocked their individual oxygen masks.
11. The subjects had been worn the individual oxygen masks after they showed the individual first sign of hypoxic hypoxia and/or the insided observers had judged them to wear by the aviation medicine regulation. The testing time was stopped at the same time.

12. To continue with the other 5 subjects. After finishing the test of all subjects, the chamber operator decreased the altitude to 3,000 feet MSL with the climbing rate is 300 feet/min.

Figure 3.4 Hypobaric Chamber for The Time of Useful Consciousness Measurement

Figure 3.5 The Time of Useful Consciousness Measurement

13. To clear the trap gas in their body and recheck the readiness for landing at 3,000 feet MSL.
14. After landing to the ground altitude, all subjects were interviewed about the reason to stop their individual testing time and their after-flight symtoms (if it was available).
15. To ask all subjects about their sleeping history and fill the pertentage of self-judgement physical fitness score.

Protocol

The Hypobaric Hypoxic Training Program

Observed Parameters

- The resting heart rate (beat per minute ; bpm)
- The arterial oxygen saturation (percentage ; $\%SaO_2$)

Methods

1. The volume of the training program is 14 periods. The period is 1 hour per day.
2. The training altitude are 10,000 feet MSL for the first 9 periods and 12,000 feet MSL for the last 5 days.
3. This trianing program was continued consecutively every officed day except the weekend day.
4. The subjects have to participate in this program every operating days and they were allow to miss the training program not more than 3 days continuously.
5. Only subjects in the experimental group were trained in the hypobaric chamber for 1 hour per day by sitting comfortably inside this chamber.
6. The chamber operator will operate the hypobaric chamber to the target altitude at 10,000 feet MSL with the climb rate is 300 ft./min. The recorder has counted the time of the training duration when the pressurization inside the hypobaric chamber matched for the target altitude of that training period.

7. After 1 hour of the training period, the chamber operator flied down to the normal ground altitude with the climb rate is 1,200 ft./min.

Figure 3.6 Environment during the Hypobaric Hypoxic Training Period
at 10,000 – 12,000 feet

Data Collection

1. To do the previous measurements for the pre-test and post test measurements
2. To run the Hypobaric Hypoxic Training Program which the period per day is 1 hour and do 14 periods continuously except the weekend days. It is for the experimental group only.
3. To collect the post-test data of this study on the day after the final training day in both groups and follow the effect of this training for 1 week (Day-1, 3, 5, 7) especially for the experimental group.

Data Analysis

1. All data were analyzed by the Statistic Package for the Social Sciences (SPSS for Windows version 17.0, Chicago,IL, USA).
2. Mean (M) and standard deviations (SD) were computed.
3. Mann-Whitney test was applied to analyze the data of the hypoxic ventilatory response and time of useful consciousness for identifing significant differences between the trained and untrained groups in the hypobaric chamber.
4. Paired t-test was utilized for analyzing the individual comparisons of the pre-test and post-test averaged values of the duration of time of useful consciousness within the trained group.
5. The significance level of $p<0.05$ was determined to be statistical significant.
6. Statistic analyzing the pre-test and post-test data.
7. To conclusion the results and information in this study.

Experimental Framework

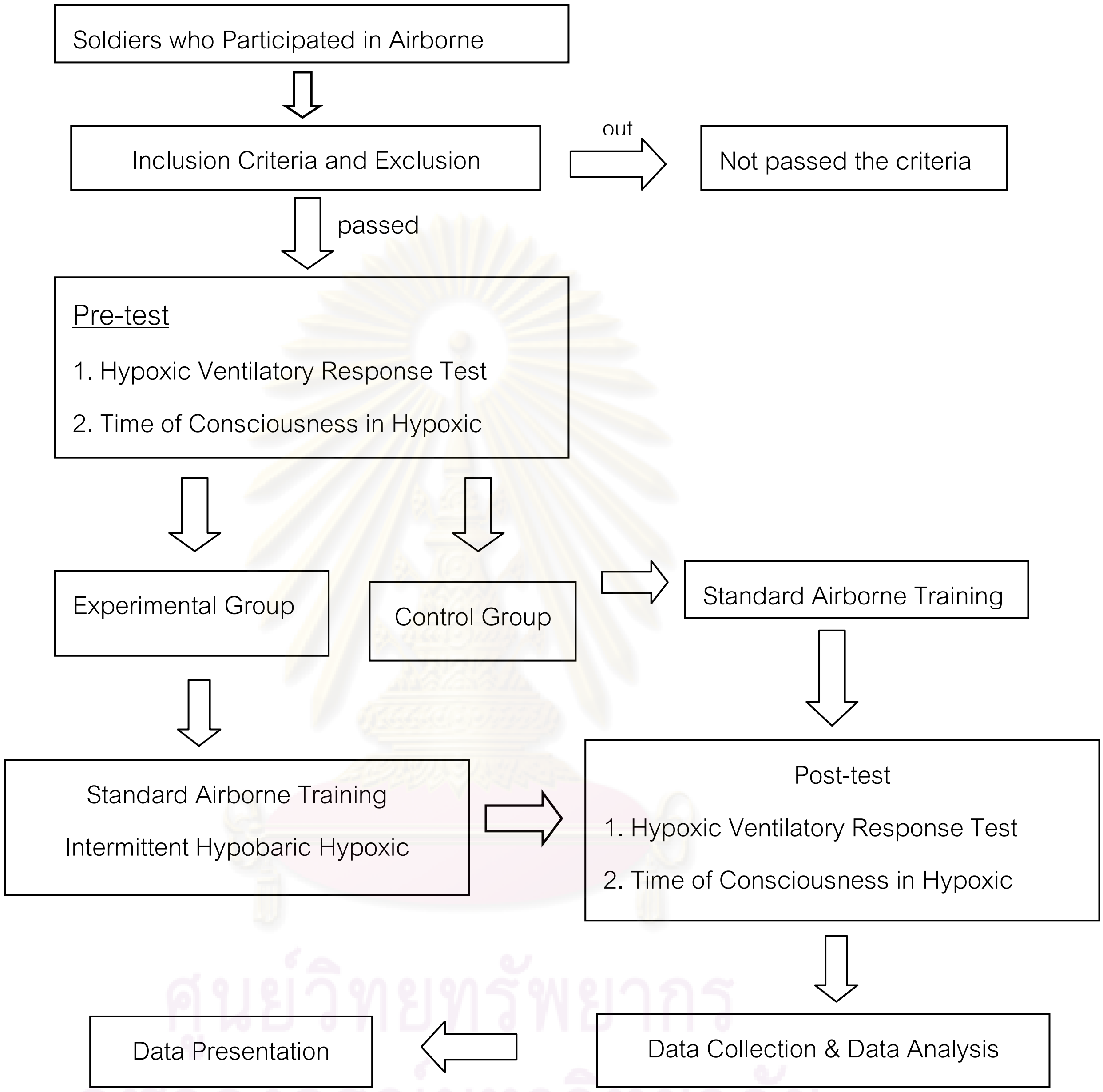


Figure 3.7 Experimental Framework

CHAPTER IV
RESULTS

A total 28 Thai airborne personnels are recruited to participate in this study. All subjects were indepenent in their activities of their daily lives and military routine responsibilities, but normally their military activities were familiar to each others in the same companies. They were positioned in three different companies of the Royal Thai Air Force Special Operations Regiment. There are divided into 10 pararescuemen, 10 commandoes, 8 airborne troopers. All of them passed the military airborne qualification.

Table 4.1 Pre-tested Physical Characteristics of Trained and Untrained Groups

Physical Characteristics	Trained Groups N = 13		Untrained Groups N = 15	
	Mean	SD	Mean	SD
Age (yr)	25.69	2.29	28.80	4.65
Weight (kg)	68.69	10.23	65.47	9.86
Height (cm)	173.62	3.93	170.33	7.38
BMI (kg/m^2)	22.79	3.31	22.53	2.81
Resting Heart Rate (beat/min)	68.69	5.91	68.47	11.21
Systolic Blood Pressure (mmHg)	119.31	4.92	119.33	6.66
Dyastolic Blood Pressure (mmHg)	76.31	7.78	73.73	8.52
Resting ventilation (breath/min)	11.08	2.43	10.47	2.20
% Body Fat (precentage)	14.99	6.23	19.48	5.44
TUC (min)	7.27	1.42	6.89	2.29
VO_2max (ml/kg/min)	41.31	10.37	43.93	15.01

Value are mean ± SD.

The physical characteristics of the trained (TG) and untrained groups (UG) before participating in this study are shown in Table 4.1. Subjects were similar in height, weight, body mass index, resting heart rate, blood pressure, predicted VO_2max and the evaluated grade of physical fitness in the pre-tested measurements. For the variable ages of subjects, there are the real age range of the airborne personnel on duties, who positioned in the Royal Thai Air Force Special Operations Regiment, which do not exceed than 50 years old.

Hypoxic Ventilatory Response (HVR)

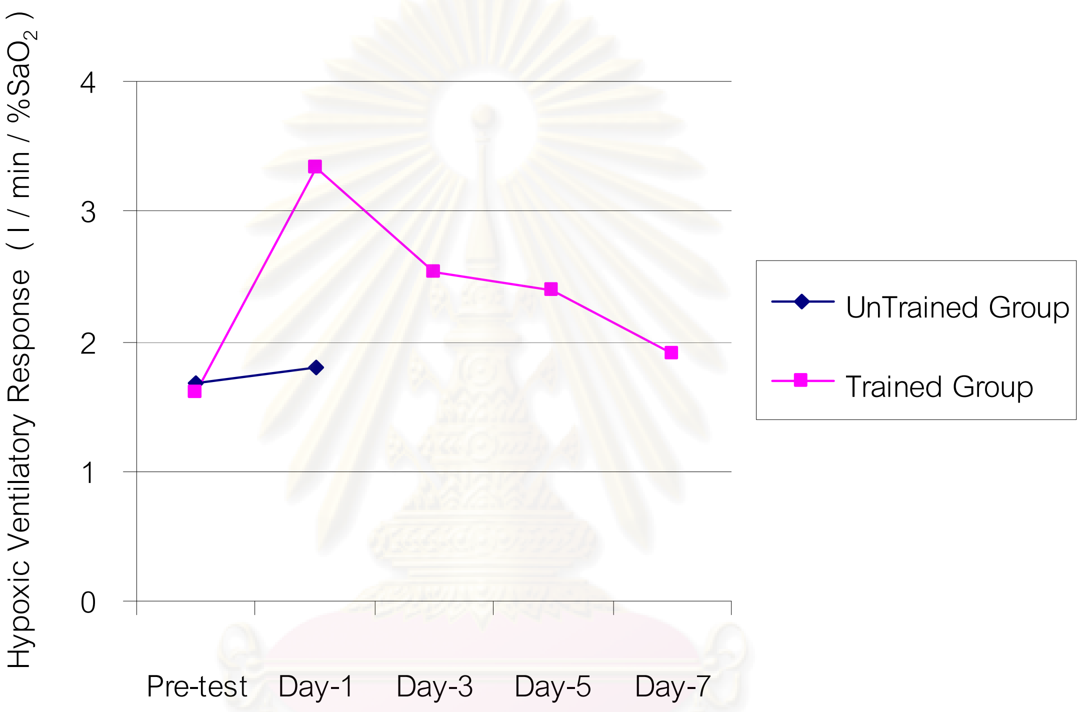


Figure 4.1 The averaged HVR in trained and untrained groups

Day-1 = The 1st day after completing the 14 hypobaric hypoxic training sessions.

Day-3 = The 3rd day after completing the 14 hypobaric hypoxic training sessions.

Day-5 = The 5th day after completing the 14 hypobaric hypoxic training sessions.

Day-7 = The 7th day after completing the 14 hypobaric hypoxic training sessions.

Figure 4.1 and 4.2 provided the averaged values of the HVR of the trained and untrained groups in the different presentations. There are 1.60 ± 0.39 and 1.67± 0.26 l/min/%SaO_2 in the pre-test of TG and UG respectively. Moreover, the averaged HVR in the post-1 test were 3.33±0.25 (UG) and 1.80±0.639 l/min/%SaO_2 (TG) which showed the significent differences between these two groups (p=0.000) in the Table 4.2.

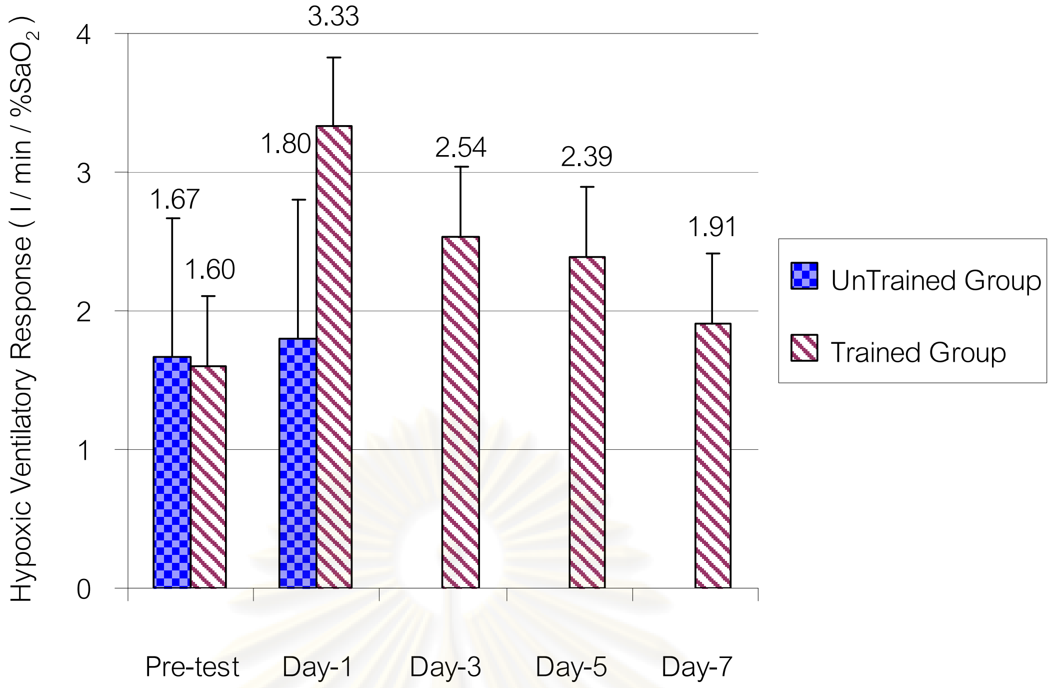


Figure 4.2 The averaged HVR in trained and untrained groups

Day-1 = The 1st day after completing the 14 hypobaric hypoxic training sessions.

Day-3 = The 3rd day after completing the 14 hypobaric hypoxic training sessions.

Day-5 = The 5th day after completing the 14 hypobaric hypoxic training sessions.

Day-7 = The 7th day after completing the 14 hypobaric hypoxic training sessions.

Table 4.2 The comparisons of the pre-test and Day-1 test on the averaged values of HVR in the trained and untrained groups.

Group	N	Pre-test	Post-test
Untrained Group (UG)	15	1.67 ± 0.26	1.80 ± 0.39
Trained Group (TG)	13	1.60 ± 0.39	3.33 ± 0.25 *

* presented the statistic significance between groups (p<0.005).

The statistic comparison between these two groups was by the nonparametric test, Mann-Whitney Test. In Table 4.2, the trained group showed the statistic significant difference between group in the post-test which was greater than 0.05. This is no significent differences between groups in the pre-test which indicated that the baseline hypoxic ventilatory response in both groups were similar.

From Figure 4.1 and 4.2 presented the declined averaged value of the trained group after accomplishing the hypobaric hypoxic training program, but all post-test values of the trained group were still higher than the post-test value of the untrained group. Moreover, if the pre-test and Day-7 values (Figure 4.2 and Table 4.2) were compared together, they showed the percentage of change was 14.49% from the pre-test of the trained group.

The hypoxic ventilatory response showed a good trend in the trained group after training, but it could not last longer than 1 week. This training protocal was supposed to be a proper additional training program for airborne troopers who prepared for the airborne missions which were not longer than 1 week.

Time of Useful Consciousness (TUC)

Table 4.3 The comparisons of the pre-test and post-test averaged values of TUC in untrained and trained groups.

Group	N	Pre-test	Post-test
Untrained Group (UG)	15	6.89 ± 2.29	5.51 ± 0.82
Trained Group (TG)	13	7.27 ± 1.42	$8.76 \pm 2.41^{*\psi}$

ψ = the statistic significance within group ($p<0.05$) by the paired t-test.

$*$ = the statistic significance between groups ($p<0.05$) by the Mann-Whitney Test.

The comparision of the individual averaged values of TUC in the pre-test and post-test was showed in Table 4.3. In the untrained group, the pre-tested value (6.89±2.29) was higher than the post-tested value (5.51±0.82), but they presented the insignificant difference ($p>0.05$) within the untrained groups. In the trained group, the pre-tested value of TUC (7.27±1.42) was less than the post-tested value (8.76±2.41) with statistic significant difference ($p<0.05$). These pre-tested and post-tested results showed the significent differences within the trained groups after the accomplishment of the 14 hypobaric hypoxic training sessions in the hypobaric chamber.

There was not significant differnce ($p>0.05$) in the pre-tested results of TG and UG in the beginning of this study before taking part in the hypobaric hypoxic training program. In addition, Table 4.3 was also shown the statistic significant differnces between the trained and untrained groups in the post-test obviously. Afterwards, the post-tested value of the trained group was significantly different ($p<0.05$) and higher than the untrained group (UG) after accomplished the 14 sessions of the intermittent hypobaric hypoxic training. The percentage of change within the trained group was showed 17%, which the pre-test and post-test mean values were compared,.

Figure 4.3 The comparisons of the pre-test and post-test on the averaged TUC of the trained (TG) and untrained (UG) groups.

The figure 4.3 showed the averaged TUC values of the untrained group were 6.89 ± 2.29 and 5.51 ± 0.82 minutes at pre-test and post-test respectively. Contrary to the mean values of the trained group were also at the higher range in the pre-test (7.27± 1.42) and the post-test (8.76±1.35) which supported a good trend for intermittent hypobaric hypoxic training to TUC. Assuredly, this hypobaric hypoxic training protocol was beneficial and proper for preparing the airborne troopers for the exclusive airborne missions.

Finally, they were concluded that the averaged time of useful consciness of the trained group (TG) was greater than the untrained group (UG) with the statistic significant differences between these two groups. Furthermore, the pre-test and post-test averaged HVR values did show the significent differences between groups. Certainly, they presented the good trend of the averaged HVR in the trained group, even though the declined HVR values were occurred. They were sitll better than the post-test value of the untrained group after finishing the intermittent hypobaric hypoxic training one week later.

CHAPTER V
DISCUSSION AND CONCLUSION

This study aimed to examine the effect of hypobaric hypoxic training on hypoxic ventilatory response and time of useful consciousness in Thai military airborne comparing with standard training. Total 28 subjects were recruited by the support of Royal Thai Air Force Special Operations Regiment for this study. They positioned in the anti-terrorism commando, pararescue and combat control, and airborne companies. They were divided into two groups as the trained (N=13) and untrained (N=15) groups. All of them did not show the differences in the baseline physiological characteristics. The means of their predicted VO_2max were also not different between the trained (TG) and untrained (UG) groups. Especially, all subjects were qualified to be the airborne troopers and they still continued their military routine activities during participating in this study.

Hypoxic Ventilatory Response (HVR)

The effect of the intermittent hypoxic training protocol in this study can influence the hypoxic ventilatory response (HVR) to enhance significantly in Thai military airborne troopers compared with the standard training. The percentage of change was 51.95% within the trained group. As same as the previous study of Katayama K. et al. (2009) stated that short-term intermittent hypoxia could induce an increase in the ventilatory chemosensitivity to hypoxia by increasing the hypoxic ventilatory response. The results showed the declined HVR values of the trained group between pre-training and after 1 week of training as similar to the study of Katayama K. et al (2002) which found the effect of HVR could stay for 1 week. Nevertheless, the mean HVR of the posted Day-7 value (Figure 4.1, 4.2) was higher than the post-test value of the untrained group. These results supported this hypothese and this protocol was suppoed to be benefit for training the airborne troopers for very important airborne missions which would not exceed than 1 week.

Although, the post-test measurement of the trained group were collected frequently on Day-1 to Day-7 after completing the 14 training sessions, but no effect of this repeated measurement as an intermittent hypoxic stimulus on the hypoxic ventilatory response. According to the study of Michael S. et al. (2005) which proved that the repeated measurement of HVR did not lead to change in HVR itself by one measurement each day during the 5-day continuous period.

Intermittent Hypobaric Hypoxic Training Program

This study used the short intermittent hypoxic training which lasted one hour per day. These intermittent hypoxic training program was run continuously on Monday to Friday morning of the official working day of Royal Thai Air Force and paused on Saturday to Sunday. Because the hypobaric chamber is occupied by the Institute of Aviation medicine, Royal Thai Air Force which opened only on the official day. This reason was one of our questions to prove if we had used the hypobaric chamber, which was for improving the hypoxic ventilatory response in Thai military airborne troopers under the limited consecutive training day for some periods whether the effect of discontinued hypoxic training could be found and how long that it could remain.

The subjects were asked to relax on comfortable chair (Katayama K. et al., 2002) and exposed 1 hour per day in the hypobaric chamber. The volume of training to complete this intermittent hypoxic training program was total 14 sessions or hours which followed the previous study (Hector C. et al., 2000). Inside the hypobaric chamber, the brain training games were prepared such as the chess, dominoes, cards, and rubik's cubes for subjects to play desirably. The games were benefit for early analyzing the incidents of hypoxia during training sessions. The aviation oxygen mask and other equipments were provide inside the chamber for emergency use.

Hector C. et al. (2000) compared the three intermittent hypoxic training protocols which were different in duration (day) and exposure (hour) at the simulated altitudes (12,000-16,500 feet). One of them, which was 21 alternated day sessions with 14 hours

(1.5 hours per day), was be chosen to be a model for this study, caused it could affect the haematological adaptive responses under inconsecutive periods. From the other study of Katayama K. et al. (2009) supported that the 1-hour exposure in the hypobaric chamber could increase the hypoxic ventilatory response (HVR) as good as the 3-hour exposure.

Katayama K. et al. (2002) found the effect of the intermittent hypoxic training program with 1 hour for 7 consecutive days could increase the resting hypoxic ventilatory response significantly which elevated the peripheral chemosensitivity to hypoxia. The results did not show the effect the ventilatory response during maximal and submaximal exercise at sea level and not found an insignificant change in the hypercapnic ventilatory response, which did not support their hypothesis.

Time of Useful Consciousness (TUC)

The baseline TUC at the pre-test in the trained and untrain groups were not significant diferrence due to the similarity of the physiological characteristics and their military routine activities. The mean values of the trained group were 7.27±1.42 and 8.76 ± 2.41 minutes of pre-test and post-test, respectively. The averaged values of the untrained group were 6.89 ± 2.41 and 5.51± 0.82 minutes for pre-test and post-test, orderly. The declined mean value of TUC in the untrained group were similar to the study of Izraeli S. et al. (1988) which showed the first exposured mean value of TUC (4.46 minutes) was higher than the second exposure (4.00 minutes) at 25,000 feet. The declined mean value of TUC was caused by the variable daily activities of subjects which could influence the time of useful consciousness to present the unstable time records in some occassions. Only three subjects of the trained group and some of them in the untrained group showed the decreased time records in the post-test which was due to their overnight military operations before taking part in this post-test of TUC. Because the operated period of this study was between the 2010 Thai political red-shirted crisis period in the era of Prime Minister Abhisit Vejjajiva, these small group of subjects could not be controlled their unexpected daily missions.

The result showed the siginificant difference in the post-test between the trained and untrained groups with 37.10% of diferrence. These results showed a benefit for the trained airborne group with the intermittents hypobaric hypoxic training and promoted the aviation safety during the high risk flight of hypoxia.

At 25,000 feet, the TUC was found as long as 3-5 minutes up to the baseline physiological characteristics (Aviation Medicine,1999). In this study, almost all subjects in the trained group could get the good time records for their TUC. Realistically, they could go further than 10 minutes, but the time was limited at 10 minutes because of the safety policy of the Institute of Aviation Medicine. It was conclued the subjects who could get the time record at 10 minutes were classified in an excellent level of this TUC measurement.

Playing the form fitter toy for children under 18 months during the TUC test at 25,000 ft. which is a good indicator for earlier analyzing the incidents of hypoxia during the test. The criterior of the hypoxic incidents with this toy is inability to match shapes and texture continuously. In the other study, the researher used the fundamental mathematic exercise test such as fullfilment of the two digits munbers correctly, but it was a difficult procedure to analyze the happening errors of the nearly unconscious subjects. Some of them took too much time for calculating the mathematic questions, so it would be a problem to identify the signs and symptoms of hypoxia within the real time.

Conclusions

The effect of the hypobaric hypoxic training on hypoxic ventilatory response (HVR) could imporve by the intermittent hypobaric hypoxic training and the intermittent hypobaric hypoxic training could also extend the time of useful consciousness in Thai military airborne compared with standard training after accomplishing 14 sessions of hypobaric hypoxic training in the trained group. After 1 week of training completion, the HVR results of the trained group declined gradually, but these results were still higher than the post-test of the untrained group. This identified that the trained group showed the successful results. Therefore, this training protocol was prpoer for Thai military airborne troopers to increase their hypoxic ventilatory response and extend the duration of time of useful consciousness which was better than using the standard training only.

This study promoted the aviation safety during the exclusive missions of Royal Thai Air Force Special Operations Regiment that the airborne missions would not exceed than 1 week.

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APPENDICES

APPENDIX A

ใบยินยอมเข้าร่วมการวิจัย (Consent form)

การวิจัยเรื่อง **ผลของการตอบสนองในการหายใจต่อภาวะพร่องออกซิเจนหลังผ่านการฝึกสภาวะพร่อง ออกซิเจนที่ระดับความดันบรรยากาศต่ำเมื่อเทียบกับการฝึกแบบมาตรฐานในทหารพลร่มไทย**

วันให้คำยินยอม วันที่ .... เดือน......................... พ.ศ. ....

ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยครั้งนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตราย หรืออาการที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่เกิดขึ้นจากการวิจัยอย่างละเอียด และมีความเข้าใจดีแล้ว

ผู้วิจัยรับรองว่าจะตอบคำถามต่างๆ ที่ข้าพเจ้าสงสัยด้วยความเต็มใจ ไม่ปิดบังซ่อนเร้นจนข้าพเจ้าพอใจ

ข้าพเจ้าเข้าร่วมโครงการวิจัยนี้โดยสมัครใจ และสามารถบอกเลิกการเข้าร่วมการวิจัยนี้ได้ตลอดเวลา

ผู้วิจัยรับรองว่าจะเก็บข้อมูลเฉพาะเกี่ยวกับตัวข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะในรูปที่เป็นสรุปผลการวิจัย การเปิดเผยข้อมูลเกี่ยวกับตัวข้าพเจ้าต่อหน่วยงานต่างๆ ที่เกี่ยวข้อง กระทำได้เฉพาะกรณีจำเป็น ด้วยเหตุผลทางวิชาการเท่านั้น

ผู้วิจัยรับรองว่าหากเกิดอันตรายใดๆ จากการวิจัยดังกล่าว ข้าพเจ้าจะได้รับการรักษาพยาบาลในโรงพยาบาลจุฬาลงกรณ์ โดยไม่คิดค่าใช้จ่ายใดๆ

ข้าพเจ้าได้อ่านข้อความข้างต้นแล้ว และมีความเข้าใจดีทุกประการ และได้ลงนามในใบยินยอมนี้ ด้วยความเต็มใจ

ลงนาม...ผู้ยินยอม

(..)

ลงนาม...พยาน

(..)

ลงนาม...ผู้ทำวิจัย

(..)

APPENDIX B

แบบสอบถามข้อมูลเพื่อคัดกรองขั้นต้น

เลขที่…………

1. เพศ O ชาย O หญิง
2. อายุ…………ปี
3. สัญชาติ O ไทย O อื่นๆ
4. สภาวะสุขภาพ O ดีมาก O ดี O ไม่ดี
5. การออกกำลังกาย O เป็นประจำ O เป็นครั้งคราว O ไม่เคย
6. ท่านมีประวัติเป็นโรคหัวใจ หรือไม่

   O เป็น O ไม่เป็น O ไม่แน่ใจ
7. ท่านเคยมีอาการเจ็บแน่นบริเวณหน้าอกขณะออกกำลังกายหรือขณะพักหรือไม่

   O เป็น O ไม่เป็น O ไม่แน่ใจ
8. ท่านมีประวัติเป็นโรคความดันโลหิตสูงหรือไม่

   O เป็น O ไม่เป็น O ไม่ทราบ

   ถ้าเป็น ท่านทานยาควบคุมความดันชื่ออะไร

   ....
9. ท่านมีประวัติเป็นโรคหลอดเลือดส่วนปลายหรือไม่

   O เป็น O ไม่เป็น O ไม่ทราบ
10. ปัจจุบันท่านมีอาการเสียการทรงตัว วิงเวียน หรือหมดสติหรือไม่

    O เป็น O ไม่เป็น
11. ท่านมีประวัติเป็นโรคหอบหืด โรคถุงลมโป่งพอง หรือโรคปอดเรื้อรังหรือไม่

    O เป็น O ไม่เป็น O ไม่แน่ใจ
12. ท่านมีประวัติเป็นโรคตับหรือไม่

    O เป็น O ไม่เป็น O ไม่ทราบ
13. ท่านมีประวัติเป็นโรคไตหรือไม่

    O เป็น O ไม่เป็น O ไม่ทราบ
14. ท่านมีประวัติเป็นโรคต่อมไทรอยด์หรือไม่

    O เป็น O ไม่เป็น O ไม่ทราบ

15. ท่านมีประวัติเป็นโรคเบาหวานหรือไม่

O เป็น O ไม่เป็น O ไม่ทราบ

16. ท่านมีปัญหาการบาดเจ็บหรือผิดปกติเกี่ยวกับระบบกล้ามเนื้อ กระดูก และข้อต่อหรือไม่

O มี เจ็บหรือผิดปกติที่........................... O ไม่มี

17. ปัจจุบันท่านรับประทานยา หรือ วิตามินใดเป็นประจำ (โปรดระบุรายละเอียด)

....

....

APPENDIX C

แบบสอบถามข้อมูลส่วนบุคคล

เลขที่………… วันที่…………เดือน……………พ.ศ…………

1. เพศ O ชาย O หญิง

2. อายุ…………ปี วัน/เดือน/ปีเกิด………/………/…………..

3. การศึกษา

O มัธยมศึกษาตอนปลาย/ปวช. O ปวส.
O ปริญญาตรี O สูงกว่าปริญญาตรี

4. การออกกำลังกาย O เป็นประจำ O เป็นครั้งคราว O ไม่เคย

ชนิดกิจกรรมที่ท่านออกกำลังกาย

1. ....………… ใช้เวลา.................นาที/ชั่วโมง/วัน.............…วัน/สัปดาห์
2. ....………… ใช้เวลา.................นาที/ชั่วโมง/วัน..............วัน/สัปดาห์
3. ....………… ใช้เวลา.................นาที/ชั่วโมง/วัน..........…วัน/สัปดาห์

รวม ท่านออกกำลังกายประมาณ…………………ชั่วโมง / สัปดาห์/ เดือน

ท่านออกกำลังกายมาแล้วประมาณ……………… เดือน……………ปี

5.จากผลการตรวจโรคประจำปีจากโรงพยาบาลต้นสังกัดนั้นไม่พบโรคใดผิดปกติ

O ใช่ O ไม่ใช่

6.จากผลการตรวจโรคจากโรงพยาบาลต้นสังกัดนั้นไม่พบโรคใดที่เป็นข้อห้ามทางการบิน

O ใช่ O ไม่ใช่

7. ท่านสูบบุหรี่หรือไม่ O สูบ O ไม่สูบ

ท่านสูบบุหรี่ประมาณ…………มวน ต่อ วัน/สัปดาห์/เดือน

เลิกมา ………วัน …………เดือน ………ปี

8. ท่านดื่มแอลกอฮอล์หรือไม่ O ดื่ม O ไม่ดื่ม

ถ้าดื่ม ปริมาณที่ดื่ม…………แก้ว/วัน ความถี่…………… ครั้ง/สัปดาห์

ชนิดของเครื่องดื่มที่ท่านดื่ม…………………………………………………

9. ภายใน 1 ปีที่ผ่านมา ท่านได้รับการตรวจไขมันในเลือดหรือไม่

O ตรวจ ระดับไขมันเท่ากับ..................... O ไม่ได้ตรวจ

10. ภายใน 1 ปีที่ผ่านมา ท่านได้รับการตรวจน้ำตาลในเลือดหรือไม่

O ตรวจ ระดับน้ำตาลเท่ากับ.................... O ไม่ได้ตรวจ

11. ท่านมีบุคคลในครอบครัวเสียชีวิตจากโรคหัวใจและหลอดเลือดหรือไม่

O ใช่ โปรดระบุ………………… O ไม่ใช่ O ไม่แน่ใจ

12. ท่านมีอาการบาดเจ็บทางร่างกายใดที่เป็นอุปสรรคต่อการออกกำลังกายด้วยการวิ่งหรือการปั่นจักรยานในช่วงระยะเวลาที่เข้าร่วมงานวิจัยหรือไม่

O ใช่ โปรดระบุ…………………… O ไม่ใช่ O ไม่แน่ใจ

13. ท่านเคยมีอาการพร่องออกซิเจน (Hypoxia) ขณะอยู่ภายในห้องโดยสารเครื่องบินที่ระดับความสูงต่างๆหรือไม่

O ใช่ โปรดระบุระดับความสูง…………………… O ไม่ใช่ O ไม่แน่ใจ

14. ท่านเคยมีอาการพร่องออกซิเจน(Hypoxia) ที่ระดับความสูงต่างๆ เมื่อกระโดดร่มออกจากอากาศยานไปแล้วหรือไม่

O ใช่ โปรดระบุระดับความสูง........................ O ไม่ใช่ O ไม่แน่ใจ

<u>หมายเหตุ</u>

บุคคลที่สามารถติดต่อได้ในกรณีฉุกเฉิน : ....

เบอร์โทรศัพท์ที่สามารติดต่อได้ในกรณีฉุกเฉิน : ....

APPENDIX D

วันที่…………เดือน……………พ.ศ………

แบบบันทึกผลการทดสอบก่อนเข้ารับการฝึก (Pre-Test Form)

เลขที่…………

1. น้ำหนัก………………กิโลกรัม

2. ส่วนสูง………………เซนติเมตร ดัชนีมวลกาย………………กิโลกรัม/เมตร^2

3. อัตราการเต้นของหัวใจขณะพัก……………ครั้ง/นาที

4. ระดับความดันโลหิตขณะพัก………………………มม.ปรอท

5. อัตราการการหายใจขณะพัก……………ครั้ง/นาที

6. ระดับเปอร์เซ็นต์ไขมัน (7-Site Skin Fold) …………………….... %

7. ระยะเวลาครองสติ (ที่ความสูง 25,000 ฟุต MSL) …………………….... นาที

8. Hypoxic Ventilatory Response …………………….... L/min/%

วันที่...........เดือน..............พ.ศ.........

แบบบันทึกผลการทดสอบหลังเสร็จสิ้นเข้ารับการฝึก (Post-Test Form)

การทดสอบครั้งที่ .... เลขที่...........

1. น้ำหนัก.................กิโลกรัม
2. ส่วนสูง.................เซนติเมตร ดัชนีมวลกาย.................กก./ม^2
3. อัตราการเต้นของหัวใจขณะพัก..............ครั้ง/นาที
4. ระดับความดันโลหิตขณะพัก..........................มม.ปรอท
5. อัตราการการหายใจขณะพัก..............ครั้ง/นาที
6. ระดับเปอร์เซ็นต์ไขมัน (7-Site Skin Fold) ....%
7. ระยะเวลาครองสติ (ที่ความสูง 25,000 ฟุต MSL) .... นาที
8. Hypoxic Ventilatory Response .... L/min/%

อุปสรรค...
....
....

สรุป..
....
....

เพิ่มเติม...
....
....

APPENDIX E

Hypoxic Ventilatory Response of Trained Group

No.	pre-test	Day-1	Day -3	Day -5	Day -7
c-1	1.28	3.63	3.42	2.77	1.92
c-2	1.16	3.03	2.02	1.96	1.87
c-3	1.27	3.29	3.05	2.42	2.04
c-4	1.21	3.82	2.13	2.13	1.94
c-5	1.43	3.51	2.41	2.00	1.89
c-6	1.08	3.20	2.47	2.07	1.76
c-7	2.19	3.10	2.03	2.03	1.74
c-8	1.96	3.40	2.93	2.30	2.05
c-9	1.86	3.64	2.43	2.61	2.00
c-10	1.86	3.19	2.38	2.02	1.73
c-11	2.16	3.22	2.41	3.47	1.78
c-12	1.62	3.08	2.58	2.33	2.04
c-13	1.77	3.20	2.76	2.93	2.07
AVERAGED	1.60	3.33	2.54	2.39	1.91
SD	0.39	0.25	0.41	0.45	0.13

APPENDIX F

Hypoxic Ventilatory Response of Untrained Group

Group	Pre-test	Post-test
s-3	1.53	1.59
s-6	1.44	1.46
s-7	1.81	1.79
s-8	1.61	1.93
s-9	1.70	1.77
s-10	1.71	1.73
s-12	1.44	1.28
s-13	1.08	1.83
s-14	1.42	1.84
s-15	1.83	1.75
s-16	1.98	1.01
s-17	1.64	2.62
s-18	1.96	2.02
s-19	1.93	2.39
s-20	1.97	1.95
N	15	15
Averaged	1.67	1.80
SD	0.26	0.39

APPENDIX G

Time of Useful Consciousness (TUC)				
No.	Trained Group		Untrained Group	
	Pre-test	Post-test	Pre-test	Post-test
1	8.35	11.35	5.16	6.48
2	3.26	2.51	10.25	4.3
3	7.47	7.19	6.53	6.4
4	7.1	9.11	11.31	6.3
5	8.2	9.38	10.25	4.2
6	9.06	9.15	5.11	5.13
7	7.15	10.25	6.39	4.88
8	7.28	10.25	10.1	5.51
9	7.02	9.38	5.58	5.53
10	7.47	10.25	5.29	6.5
11	8.57	10.25	5.32	4.42
12	6.35	5.43	5.5	5.8
13	7.21	9.39	5.46	5.55
14			5.59	5.11
15			5.48	6.5
N	13	13	15	15
Averged	7.27	8.76	6.89	5.51
SD	1.42	2.41	2.29	0.82

Appendix H

Descriptive Survey Data of Thai Military Airborne Troopers

ตารางที่ 1 ข้อมูลทั่วไปของผู้ตอบแบบสอบถามของนักกระโดดร่ม

ข้อมูลทั่วไป		นักกระโดดร่ม n=267	
		จำนวน	**ร้อยละ**
1	**เพศ**		
	ชาย	192	71.9
	หญิง	75	28.1
2	**อายุ**		
	20-30 ปี	49	18.4
	31-40 ปี	62	23.2
	41-50 ปี	128	47.9
	มากกว่า 50 ปี	28	10.5
	อายุเฉลี่ย 40.9 ปี		
3	**สังกัด**		
	ตำรวจ	26	9.7
	ทหารเรือ	31	11.6
	ทหารอากาศ	130	48.7
	ทหารบก	80	30.0
4	**การศึกษา**		
	มัธยมศึกษาตอนปลาย/ปวช.	135	50.6
	ปวส.	34	12.7
	ปริญญาตรี	92	34.5
	สูงกว่าปริญญาตรี	6	2.2
5	**สัญชาติ**		
	ไทย	267	100.0
6	**โรคประจำตัว**		
	ไม่ทราบ	19	7.1
	ไม่มี	229	85.8
	มี (ไทรอยด์, ภูมแพ้, ความดัน)	19	7.1

7	**น้ำหนัก** (kg.)		
	น้ำหนักเฉลี่ย (kg.)	*62.7*	
8	**ส่วนสูง** (cm.)		
	ความสูงเฉลี่ย (cm.)	*166.6*	
9	**สถานภาพครอบครัว**		
	โสด	72	27.0
	สมรส	185	69.3
	หย่าร้าง	10	3.7
10	**ท่านสูบบุหรี่หรือไม่**		
	ไม่สูบ	215	80.5
	สูบ *(สูบบุหรี่เฉลี่ย 12 มวน/วัน)*	42	15.7
	เลิกสูบแล้วเฉลี่ย 12.5 ปี	10	3.7
11	**ประวัติการดื่มแอลกอฮอล์** *(ดื่มแอลกอฮอล์เฉลี่ย 86 แก้ว/เดือน)*		
	ไม่ดื่ม	150	56.2
	ดื่ม (เหล้า, เบียร์)	109	40.8
	เลิกดื่มเฉลี่ย 1.5 ปี	8	3.0
12	**การนอนหลับพักผ่อนเฉลี่ยต่อในยามปกติ**		
	นอนหลับพักผ่อนมากที่สุด (ชั่วโมง/วัน) 12 ชม./วัน	*12*	
	นอนหลับพักผ่อนน้อยที่สุด (ชั่วโมง/วัน) 3 ชม./วัน	*3*	
	นอนหลับพักผ่อนเฉลี่ย (ชั่วโมง/วัน) 7.9 ชม./วัน	*7.9*	
13	**ประวัติการรับประทานยาควบคุมโรคต่างๆ**		
	ไม่ได้รับประทานยาใดๆ เลย	227	85.0
	รับประทาน (ยาแก้ภูมิแพ้, ความดัน, ไข้หวัด, ไทลอยด์, เบาหวาน)	37	13.9
	เลิกรับประทานยาแล้ว	3	1.1

ตารางที่ 2 ข้อมูลด้านการกระโดดร่มของผู้ตอบแบบสอบถามของนักกระโดดร่ม

	ข้อมูลด้านการกระโดดร่ม	นักกระโดดร่ม n=267	
		จำนวน	ร้อยละ
1	**ประวัติการกระโดดร่มประเภทสายดึงประจำที่ (Static Line) หรือไม่**		
	เคย	253	94.8
2	**จำนวนครั้งในการกระโดดร่มประเภทสายดึงประจำที่ (Static Line)**		
	ทำการกระโดดร่มแบบต่อสาย (Static Line) มาแล้วมากที่สุด (ครั้ง)	1,000	
	ทำการกระโดดร่มแบบต่อสาย (Static Line) มาแล้วน้อยที่สุด (ครั้ง)	5	
	ทำการกระโดดร่มแบบต่อสาย (Static Line) มาแล้วเฉลี่ย (ครั้ง)	41	
3	**ประวัติการกระโดดร่มแบบกระตุกเอง (Free Fall)**		
	เคย	267	100.0
4	**จำนวนครั้งในการกระโดดร่มแบบกระตุกเอง (Free Fall)**		
	ทำการกระโดดร่มแบบกระตุกเอง (Free Fall) มาแล้วมากที่สุด (ครั้ง)	15,000	
	ทำการกระโดดร่มแบบกระตุกเอง (Free Fall) มาแล้วน้อยที่สุด (ครั้ง)	3	
	ทำการกระโดดร่มแบบกระตุกเอง (Free Fall) มาแล้วเฉลี่ย (ครั้ง)	1,004	
5	**ระดับความสูงที่ทำการกระโดดร่มเป็นประจำ (ฟุต)**		
5.1	**ระดับความสูงต่ำสุดที่ทำการกระโดดร่มเป็นประจำ**		
	400 ถึง 1,000 ฟุต	5	1.9
	1,100 ถึง 2,000 ฟุต	15	5.6
	2,100 ถึง 3,000 ฟุต	7	2.6
	3,100 ถึง 4,000 ฟุต	127	47.6
	4,100 ถึง 5,000 ฟุต	23	8.6
	5,100 ถึง 6,000 ฟุต	15	5.6
	7,100 ถึง 8,000 ฟุต	70	26.2
	9,100 ถึง 10,000 ฟุต	3	1.1
	12,000 ฟุต	1	0.4
	40,000 ฟุต	1	0.4
5.2	**ระดับความสูงที่สูงสุดที่ทำการโดดร่มเป็นประจำ**		
	400 ถึง 1,000 ฟุต	3	1.1
	1,100 ถึง 2,000 ฟุต	11	4.1

	3,100 ถึง 4,000 ฟุต	14	5.2
	4,100 ถึง 5,000 ฟุต	5	1.9
	5,100 ถึง 6,000 ฟุต	22	8.2
	6,100 ถึง 7,000 ฟุต	2	0.7
	7,100 ถึง 8,000 ฟุต	18	6.7
	9,100 ถึง 10,000 ฟุต	156	58.4
	10,100 ถึง 11,000 ฟุต	2	0.7
	11,100 ถึง 12,000 ฟุต	21	7.9
	12,100 ถึง 13,000 ฟุต	7	2.6
	13,100 ถึง 14,000 ฟุต	1	0.4
	14,100 ถึง 15,000 ฟุต	4	1.5
	17,000 ฟุต	1	0.4
6	**ระยะความสูงที่สูงที่สุดที่ทำการกระโดดร่ม (ฟุต)**		
	1,100 ถึง 2,000 ฟุต	12	4.5
	3,100 ถึง 4,000 ฟุต	7	2.6
	4,100 ถึง 5,000 ฟุต	4	1.5
	5,100 ถึง 6,000 ฟุต	6	2.2
	6,100 ถึง 7,000 ฟุต	2	0.7
	7,100 ถึง 8,000 ฟุต	12	4.5
	8,100 ถึง 9,000 ฟุต	1	0.4
	9,100 ถึง 10,000 ฟุต	92	34.5
	10,100 ถึง 11,000 ฟุต	12	4.5
	11,100 ถึง 12,000 ฟุต	48	18.0
	12,100 ถึง 13,000 ฟุต	20	7.5
	13,100 ถึง 14,000 ฟุต	2	0.7
	14,100 ถึง 15,000 ฟุต	16	6.0
	15,100 ถึง 16,000 ฟุต	2	0.7
	16,100 ถึง 17,000 ฟุต	8	3.0
	17,100 ถึง 18,000 ฟุต	11	4.1
	18,100 ถึง 19,000 ฟุต	2	0.7
	19,100 ถึง 20,000 ฟุต	1	0.4

	20,100 ถึง 21,000 ฟุต	1	0.4
	24,000 ฟุต	1	0.4
	25,000 ฟุต	6	2.2
	41,000 ฟุต	1	0.4
7	**ระดับความสูงที่ต่ำที่สุดที่เคยทำการกระโดดร่ม (ฟุต)**		
	600 ถึง 1,000 ฟุต	45	16.9
	1,100 ถึง 2,000 ฟุต	118	44.2
	2,100 ถึง 3,000 ฟุต	59	22.1
	3,100 ถึง 4,000 ฟุต	36	13.5
	4,100 ถึง 5,000 ฟุต	4	1.5
	5,100 ถึง 6,000 ฟุต	1	0.4
	7,100 ถึง 8,000 ฟุต	1	0.4
	11,100 ถึง 12,000 ฟุต	2	0.7
	12,100 ถึง 13,000 ฟุต	1	0.4
8	**ระดับความรู้เรื่องสรีรวิทยาการบินหรือเวชศาสตร์การบินของนักกระโดดร่ม**		
	ดีมาก	5	1.9
	ดี	82	30.7
	ปานกลาง	87	32.6
	เล็กน้อย	47	17.6
	ไม่มีความรู้เรื่องนี้	46	17.2
9	**ระดับความรู้เรื่องการพร่องออกซิเจน**(Hypoxia)**เมื่ออยู่บนที่สูง**		
	ทราบ	214	80.1
	ไม่ทราบ	53	19.9
10	**ประวัติการเกิดอาการผิดปกติทางด้านร่างกายเช่น ร่างกายไม่ประสานกัน การมองเห็น เลวลง การตอบสนองช้าลง หน้ามืดชั่วขณะ วิงเวียนศีรษะ ตาลาย ฯลฯ <u>ก่อนขึ้นอากาศยาน</u> ของนักกระโดดร่ม**		
	ไม่เคยมี	231	86.5
	ไม่ทราบ	19	7.1
	มี จำนวนเฉลี่ย 2 ครั้ง	17	6.4
11	**การปฏิบัติตนของทหารพลร่มหลังเกิดอาการบ่งชี้ในข้อ** 10		
	ไม่มีอาการใดๆ ในข้อ 10	250	93.6
	ทำการกระโดดร่มต่อ	6	2.2

	งดเว้นการกระโดดร่มในวันนั้นตลอดทั้งวัน	8	3.0
	พักในรอบนั้นจนอาการเหล่านั้นหายแล้ว จึงขึ้นทำการกระโดดร่มต่อ	3	1.1
12	**ประวัติการเกิดอาการพร่องออกซิเจน (Hypoxia) เช่น ร่างกายทำงานไม่ประสานกันการมองเห็นเลวลง การตอบสนองช้าลง หน้ามืดชั่วขณะ ฯลฯ *ขณะอยู่ภายในห้อง โดยสาร*เครื่องบินที่ระดับความสูงต่าง ๆ ของนักกระโดดร่ม**		
	- ใช่ ที่ระดับความสูงเฉลี่ย 19,900 ฟุต จำนวนเฉลี่ย 2 ครั้ง	10	3.7
	อาการในครั้งที่ 1 ปวดศีรษะและจมูกเนื่องจาก ร่างกายปรับสภาพไม่ทัน		
	อาการในครั้งที่ 2 ตาลาย แน่นหน้าอกเนื่องจาก ร่างกายปรับสภาพไม่ทัน		
	- ไม่มี	197	73.8
	- ไม่แน่ใจ	60	22.5
13	**ประวัติการเกิดอาการพร่องออกซิเจน (Hypoxia) เช่น ร่างกายทำงานไม่ประสานกัน การมองเห็นเลวลง การตอบสนองช้าลง หน้ามืดชั่วขณะ ฯลฯ ที่ระดับความสูงต่าง ๆ *เมื่อกระโดดออกจากอากาศยาน* ไปแล้วของนักกระโดดร่ม**		
	- ใช่ ที่ระดับความสูงเฉลี่ย 7,000 ฟุต จำนวนเฉลี่ย 1 ครั้ง	2	0.7
	-อาการในครั้งที่ 1 ร่างกายไม่ตอบสนอง		
	-เนื่องจาก ดื่มแอลกอฮอล์ก่อนกระโดดร่ม		
	- ไม่มี	231	86.5
	- ไม่แน่ใจ	34	12.7
14	**ประวัติการเกิดอาการพร่องออกซิเจน (Hypoxia) เช่น ร่างกายทำงานไม่ประสานกันการมองเห็นที่หมายไม่ชัดเจน การตอบสนองช้าลง หน้ามืดชั่วขณะ ฯลฯ ที่ระดับความสูงต่าง ๆ*หลังจากกระตุกร่มเรียบร้อยแล้วและพร้อมร่อนลงสู่พื้นดินของนักกระโดดร่ม***		
	- ใช่ ที่ระดับความสูงเฉลี่ย 5,000 ฟุต จำนวนเฉลี่ย 2 ครั้ง	4	1.5
	-อาการในครั้งที่ 1 หน้ามืดเนื่องจาก ไม่ได้พักผ่อน		
	-อาการในครั้งที่ 2 หน้ามืดชั่วขณะเนื่องจาก ร่างกายไม่สมบูรณ์		
	- ไม่มี	229	85.8
	- ไม่แน่ใจ	34	12.7
15	**ประวัติการประสบอุบัติเหตุต่าง ๆ ที่เกี่ยวข้องกับการกระโดดร่ม**		
	ไม่เคย	169	63.3
	เคย (เจ็บข้อเท้า, กระดูกข้อเท้า ขา และแขนหัก, กระดูกสันหลังหัก, ศีรษะกระแทกพื้น, เอ็นขาด,สลบ, หมอนรองกระดูกฉีก, กระโดดลงหลังคาบาดเจ็บเล็กน้อย, ซี่โครงหัก เป็นต้น)	98	36.7
16	**ประวัติการประสบอุบัติเหตุที่ร่มผิดปกติ แต่ยังไม่จำเป็นต้องใช้ร่มช่วย**		
	ไม่เคย	185	69.3

	เคย	82	30.7
	-อาการผิดปกติ ครั้งที่ 1 ร่มตีเกลียว เนื่องจาก ท่าทางไม่สมบูรณ์		
	-ท่านสามารถแก้ไขสถานการณ์ได้ภายใน 5 วินาที		
	-อาการผิดปกติ ครั้งที่ 2 ร่มไม่กาง เนื่องจาก สายร่มพันกัน/พับร่มไม่เรียบร้อย		
	-ท่านสามารถแก้ไขสถานการณ์ได้ภายใน 6 วินาที		
17	**ประวัติการประสบอุบัติเหตุที่ร่มผิดปกติและไม่กาง จนจำเป็นต้องใช้ร่มช่วย**		
	ไม่เคย	193	72.3
	เคย	73	27.3
	-อาการผิดปกติ ครั้งที่ 1 ร่มไม่กาง เนื่องจาก สายร่มพันกัน/พับร่มไม่เรียบร้อย		
	-ท่านสามารถแก้ไขสถานการณ์ได้ภายใน 10 วินาที		
	-อาการผิดปกติ ครั้งที่ 2 ร่มกางผิดปกติ เนื่องจาก สายร่มพันกัน/พับร่มไม่เรียบร้อย		
	-ท่านสามารถแก้ไขสถานการณ์ได้ภายใน 10 วินาที		
	-อาการผิดปกติ ครั้งที่ 3 สายร่มขาด เนื่องจาก ร่มกางแรง/ร่มเก่า		
	-ท่านสามารถแก้ไขสถานการณ์ได้ภายใน 15 วินาที		
18	**ประวัติการใช้เครื่องจ่ายออกซิเจนในการกระโดดร่ม**		
	ไม่เคย	220	82.4
	เคย	47	17.6
19	**ช่วงเวลาในการใช้เครื่องจ่ายออกซิเจน ท่านใช้ในช่วงเวลาใด**		
	ไม่เคยใช้	220	82.4
	ใช้ ก่อนกระโดดออกจากอากาศยานเท่านั้น (ใช้เฉพาะตอนอยู่ภายในอากาศยานเท่านั้น)		
	ใช้เมื่อต้องกระโดดร่มที่ความสูงเฉลี่ย 13,600 ฟุต	33	12.4
	ใช้ตลอด ตั้งแต่อยู่ภายในอากาศยานจนกระทั่งลงสู่พื้นดิน		
	ใช้เมื่อต้องกระโดดร่มที่ความสูงเฉลี่ย 15,400 ฟุต	14	5.2
20	**จากความคิดของนักกระโดดร่ม การกระโดดร่มที่ระดับความสูงต่ำ กว่า 15,000 ฟุตจะมีโอกาสเกิดอาการพร่องออกซิเจน** (Hypoxia) **หรือไม่**		
	ไม่มีแน่นอน	13	4.9
	มีแน่นอน	45	16.9
	อาจมีโอกาสเกิดขึ้นได้	188	70.4
	ไม่ทราบ	21	7.9
21	**จากประสบการณ์ของท่าน ร่างกายที่สมบูรณ์แข็งแรงนั้นจะมีโอกาสเกิดอาการพร่อง ออกซิเจน** (Hypoxia) **ได้หรือไม่**		

	ไม่มีแน่นอน	80	30.0
	มีแน่นอน	23	8.6
	อาจมีโอกาสเกิดขึ้นได้	151	56.6
	ไม่ทราบ	13	4.9
22	**ท่านคิดว่าการออกกำลังกายประจำ ส่งผลในการลดความเสี่ยงในการเกิดอาการพร่องออกซิเจน** (Hypoxia) **ได้หรือไม่**		
	ไม่ส่งผลใดๆ	7	2.6
	ช่วยลดความเสี่ยงได้ดีมาก	182	68.2
	อาจช่วยในบางโอกาส	57	21.3
	ไม่ทราบ	21	7.9
23	**จากความคิดของนักกระโดดร่ม การมีปฏิกิริยาการตอบสนองที่ไวต่อการ พร่องออกซิเจนที่ดีมีความจำเป็นหรือไม่ (***ปฏิกิริยาการตอบสนองที่ไวต่อการพร่องออกซิเจน คือการที่ร่างกายปรับตัวเพื่อให้มีความทนทานต่อสภาวะอากาศที่มีออกซิเจนเบาบาง ซึ่งหากมีปฏิกิริยาที่ดีและไว ก็จะช่วยให้เรานั้นหมดสติช้าลงกว่าเดิม***)**		
	ไม่จำเป็นเลย	5	1.9
	จำเป็นอย่างยิ่ง	191	71.5
	อาจช่วยในบางโอกาส	45	16.9
	ไม่ทราบ	26	9.7
24	**จากความคิดของนักกระโดดร่ม หากมีปฏิกิริยาการตอบสนองที่ไวต่อการพร่อง ออกซิเจนที่ดีนั้นจะช่วยลดความเสี่ยงในการเกิดอาการพร่องออกซิเจน** (Hypoxia) **ได้หรือไม่**		
	ไม่ส่งผลใดๆ	2	0.7
	ช่วยลดความเสี่ยงได้ดีมาก	182	68.2
	อาจช่วยในบางโอกาส	56	21.0
	ไม่ทราบ	27	10.1
25	**จากความคิดของนักกระโดดร่มการพร่องออกซิเจน** (Hypoxia) **นั้นเป็นสาเหตุของการ เกิดอุบัติเหตุขณะกระโดดร่มได้หรือไม่**		
	ไม่ส่งผลใดๆ	1	0.4
	มีผลอย่างยิ่ง	194	72.7
	อาจส่งผลในบางโอกาส	52	19.5
	ไม่ทราบ	20	7.5
26	**จากความคิดของนักกระโดดร่ม ปฏิกิริยาการตอบสนองที่ไวต่อการพร่อง ออกซิเจนที่ดีนั้นจะช่วยลดความเสี่ยงในการเกิดอุบัติเหตุขณะกระโดดร่มได้หรือไม่**		

	ไม่ส่งผลใดๆ	3	1.1
	ช่วยลดความเสี่ยงได้ดีมาก	198	74.2
	อาจช่วยในบางโอกาส	42	15.7
	ไม่ทราบ	24	9.0
27	**จากความคิดของนักกระโดดร่ม หากมีการจัดการฝึกสมรรถภาพทางกาย เพื่อเพิ่มปฏิกิริยาการ ตอบสนองที่ไวต่อการพร่องออกซิเจน *โดยไม่เสียค่าใช้จ่ายใดๆ* ท่านมี*ความสนใจ* ที่จะเข้าร่วมการฝึกนี้หรือไม่**		
	สนใจเป็นอย่างยิ่ง	165	61.8
	ไม่สนใจเลย	7	2.6
	ก็ดี ถ้ามี	95	35.6

ตารางที่ 3 ข้อมูลการออกกำลังกายของผู้ตอบแบบสอบถามของนักกระโดดร่ม

ข้อมูลการออกกำลังกาย	นักกระโดดร่ม n=267	
	จำนวน	ร้อยละ
1 **ประวัติการออกกำลังกายหรือเล่นกีฬาหรือไม่**		
เล่น	267	95.9
2 **ปัจจุบันท่านออกกำลังกายหรือเล่นกีฬาชนิดใด (ตอบได้มากกว่า 1 ข้อ)**		
เดิน	97	15.5
วิ่ง	202	32.4
ว่ายน้ำ	56	9.0
ปั่นจักรยาน	104	16.7
เทนนิส	11	1.8
ฟุตบอล	83	13.3
เล่นเวท (weight training)	31	5.0
กอล์ฟ	20	3.2
อื่นๆ (ยืดหยุ่น, ตะกร้อ, แอโรบิค, เทเบิลเทนนิส)	20	3.2
3 **ชนิดของการออกกำลังกายหรือการเล่นกีฬาที่ท่านเลือกปฏิบัติอยู่นี้ เหมาะสมกับ การเสริมสร้างสมรรถภาพร่างกายของนักกระโดดร่มหรือไม่**		
เหมาะสม	227	85.0
ไม่เหมาะสม	5	1.9
ไม่ทราบ	35	13.1
4 **ความถี่เฉลี่ยในการออกกำลังกายหรือเล่นกีฬา**		
ทุกวัน (7 วัน/สัปดาห์)	97	36.3
3-5 วัน/สัปดาห์	128	47.9
1-2 วัน/สัปดาห์	36	13.5
เดือนละ 2 ครั้ง	6	2.2
5 **ท่านคิดว่าความถี่ในการออกกำลังกายหรือเล่นกีฬาของท่านเหมาะสมกับการ**		
เสริมสร้างสมรรถภาพร่างกายของนักโดดร่มหรือไม่		
เหมาะสม	219	82.0
ไม่เหมาะสม	19	7.1
ไม่ทราบ	29	10.9

6	**ระดับความหนักโดยเฉลี่ยในการออกกำลังกายหรือเล่นกีฬา**		
	หนักมาก (ใช้กำลัง 80%-100% ของสมรรถภาพร่างกายของท่าน)	4	1.5
	ค่อนข้างหนัก (ใช้กำลัง 60%-79% ของสมรรถภาพร่างกายของท่าน)	58	21.7
	ปานกลาง (ใช้กำลัง 40%-59% ของสมรรถภาพร่างกายของท่าน)	189	70.8
	เบา (ใช้กำลังต่ำกว่า 39% ของสมรรถภาพร่างกายของท่าน)	16	6.0
7	**ท่านคิดว่าความหนักที่ท่านใช้ออกกำลังกายหรือเล่นกีฬาอยู่นี้เหมาะสมกับการ เสริมสร้างสมรรถภาพร่างกายของนักโดดร่มหรือไม่**		
	เหมาะสม	213	79.8
	ไม่เหมาะสม	20	7.5
	ไม่ทราบ	34	12.7
8	**ระยะเวลาในการออกกำลังกายหรือการเล่นกีฬาตามปกติ**		
	5-10 นาที	2	0.7
	11-15 นาที	10	3.7
	16-20 นาที	24	9.0
	21-30 นาที	58	21.7
	31-45 นาที	72	27.0
	45-60 นาที	99	37.1
	อื่นๆ (120 นาที)	2	0.7
9	**ท่านคิดว่าระยะเวลาที่ท่านใช้ออกกำลังกายหรือเล่นกีฬาอยู่นี้เหมาะสมกับการ เสริมสร้างสมรรถภาพร่างกายของนักโดดร่มหรือไม่**		
	เหมาะสม	217	81.3
	ไม่เหมาะสม	15	5.6
	ไม่ทราบ	35	13.1
10	**ช่วงเวลาในการออกกำลังกาย (ตอบได้มากกว่า 1 ข้อ)**		
	เช้า	118	31.5
	กลางวัน	15	4.0
	เย็น	239	63.7
	กลางคืน	3	0.8
11	**ท่านทราบถึงประโยชน์ของการออกกำลังกายที่มีต่อสมรรถภาพร่างกายของ นักกระโดดร่มดีเพียงใด**		
	ดีมาก	98	36.7
	ดี	103	38.6

	ปานกลาง	50	18.7
	เล็กน้อย	8	3.0
	ไม่ทราบ	8	3.0
12	**ในความคิดเห็นของท่าน ผลลัพธ์ที่ได้จากการออกกำลังกายนั้นสามารถช่วยส่งเสริม สมรรถภาพทางกายของนักกระโดดร่ม ขณะปฏิบัติหน้าที่ตามภารกิจของกองทัพในสถานการณ์จริงได้ดีเพียงใด**		
	ดีมาก	169	63.3
	ดี	69	25.8
	ปานกลาง	21	7.9
	เล็กน้อย	1	0.4
	ไม่ช่วยส่งผลใดๆ	-	-
	ไม่ทราบ	7	2.6
13	**ท่านมีสมรรถภาพที่สมบูรณ์แข็งแรงก่อนทำการกระโดดร่มในแต่ละครั้งกี่ครั้ง (หากคิดคำนวณการกระโดดร่ม 100 ครั้ง)**		
	40-59 ครั้ง	5	1.9
	60-69 ครั้ง	5	1.9
	70-79 ครั้ง	8	3.0
	80-89 ครั้ง	65	24.3
	90-99 ครั้ง	83	31.1
	100 ครั้ง	101	37.8

APPENDIX I

Physical Characteristics of Trained Group

No.	Age	Weight	Height	BMI	Resting HR	Systolic	Diastolic	Resting ventilation	%Fat	VO2 max
C-1	26	65	180	20.06	65	128	70	13	8.5	43
C-2	27	73	171	24.96	77	116	87	14	20.7	33
C-3	25	72	178	22.72	69	122	81	10	13.5	41
C-4	29	68	170	23.53	70	108	75	8	23.4	32
C-5	23	86	174	28.40	62	122	79	10	23.2	35
C-6	25	90	175	29.39	63	117	69	12	21.9	37
C-7	21	62	179	19.35	70	124	77	10	14.2	44
C-8	26	70	173	23.39	78	118	76	11	11.5	37
C-9	28	62	170	21.45	77	121	88	12	20.5	40
C-10	26	62	175	20.24	63	117	78	16	13.1	31
C-11	28	52	170	17.99	67	119	83	12	6.1	71
C-12	27	62	167	22.23	61	123	61	8	11	48
C-13	23	69	175	22.53	71	116	68	8	7.21	45
N	13	13	13	13	13	13	13	13	13	13
Mean	25.69	68.69	173.62	22.79	68.69	119.31	76.31	11.08	14.99	41.31
SD	2.29	10.23	3.93	3.31	5.90	4.92	7.78	2.43	6.23	10.37

Physical Characteristics of Untrained Group

No.	Age	Weight	Height	BMI	Resting HR	Systolic	Diastolic	Resting ventilation	% Fat	VO2 max
S-3	32	55	173	18.38	96	127	88	15	19.4	27
S-6	29	60	162	22.86	75	121	75	9	15.9	27
S-7	28	57	163	21.45	74	107	71	10	10.1	56
S-8	29	53	165	19.47	64	112	69	12	12.7	74
S-9	38	68	166	24.68	84	128	78	8	27.2	29
S-10	25	70	185	20.45	58	115	74	12	11.5	25
S-12	26	68	165	24.98	58	129	72	10	25.3	30
S-13	23	85	180	26.23	53	121	56	11	25	34
S-14	36	80	183	23.89	67	127	81	14	19.5	56
S-15	32	54	165	19.83	63	117	86	12	16.2	43
S-16	23	75	167	26.89	60	122	76	10	23.9	59
S-17	24	63	176	20.34	65	110	77	8	22.6	48
S-18	33	74	167	26.53	71	118	76	10	25.7	44
S-19	25	62	170	21.45	76	118	66	8	18.8	60
S-20	29	58	168	20.55	63	118	61	8	18.4	47
N	15	15	15	15	15	15	15	15	15	15
Mean	28.80	65.47	170.33	22.53	68.47	119.33	73.73	10.75	19.48	43.93
SD	4.65	9.86	7.38	2.81	11.21	6.66	8.52	2.20	5.44	15.01

BIOGRAPHY

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