FOUR WEEKS OF RESPIRATORY MUSCLE TRAINING IMPROVES INTERMITTENT RECOVERY PERFORMANCE BUT NOT PULMONARY FUNCTIONS AND MAXIMUM OXYGEN CONSUMPTION (VO_2 MAX) CAPACITY IN YOUNG SOCCER PLAYERS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY
CAN ÖZGİDER

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF MASTER OF SCIENCE
IN THE DEPARTMENT OF
PHYSICAL EDUCATION AND SPORTS

JUNE 2010

Approval of the Graduate School of Social Sciences

Prof. Dr. Meliha Altunışık
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science

Assoc. Prof. Settar Koçak
Head of Department

This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science

Prof. Dr. Feza Korkusuz
Supervisor

Examining Committee Members

Prof. Dr. Ömer Geban (METU, SSME) _____________________

Prof. Dr. Feza Korkusuz (METU, PES) _____________________

Assoc. Prof. Settar Koçak (METU, PES) _____________________

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

Name Surname	: Can Özgider
Signature	:

ABSTRACT

FOUR WEEKS OF RESPIRATORY MUSCLE TRAINING IMPROVES INTERMITTENT RECOVERY PERFORMANCE BUT NOT PULMONARY FUNCTIONS AND VO_2 MAX CAPACITY IN YOUNG SOCCER PLAYERS

Özgider, Can

M.S., Department of physical Education and Sports
Supervisor: Prof. Dr. Feza Korkusuz
September 2009, 56 pages

The purpose of this study was to determine the effects of 4 week respiratory muscle training (RMT) on intermittent recovery performance, pulmonary functions and maximum oxygen consumption capacity (Vo_2max) of young soccer players. Eighteen young soccer player who were playing in the Turkey PAF League (league for candidate professional soccer players) from Hacettepe Sports Club with a mean age of 18.4 ± 0.8 years (ranging from 17 to 19 years) and 8.5 ± 0.7 (ranging from 7 to 9 years) years experience in soccer participated. Players' weekly metabolic equivalent score (MET) was 120. Their maximum oxygen consumption (Vo_2max) on a treadmill, pulmonary function with a spirometer, and recovery performance with a yo-yo intermittent recovery test level 2 were measured and then they were randomly assigned into two groups as either RMT (n = 9) or control (n = 9). The RMT group continued both their regular training and RMT treatment with a commercially available powerlung sport respiratory muscle trainer (Powerlung Inc., TX, and USA) for 4 weeks. The control group only continued with their regular training. After completing 4 week RMT implementation (composed of 30 sets of inhalation, two times a day, 5 days of the week), the same tests were performed in order to see the effects of 4 week RMT treatment on selected parameters mentioned above. Findings of this study indicated that 4 week of RMT treatment significantly improved (% 39) yo-yo intermittent recovery test level 2 performances of the RMT group from pre to post test measurements when compared to subjects in the control group. However, there were no significant improvements in both RMT and control group's Vo_2max capacity, Vital capacity (VC), Forced vital capacity (FVC), forced expiratory flow ($FEV_{1.0}$) and Peak expiratory flow performances (PEF). As a conclusion, 4 week of RMT implementation improves the intermittent recovery performance of young soccer players.

Keywords: Vo_2max, Respiratory Muscle Training (RMT), Yo-yo Intermittent Recovery Test, Pulmonary Functions, Young Soccer Players

ÖZ

GENÇ FUTBOLCULARDA DÖRT HAFTALIK SOLUNUM KASI ANTRENMANI TOPARLANMA PERFORMANSINI GELİŞTİRİR FAKAT, SOLUNUM FONKSİYONLARINI VE MAKSİMUM OKSİJEN KULLANIM KAPASİTESİNİ (VO_2 MAX) GELİŞTİRMEZ

Özgider, Can

Yüksek Lisans, Beden Eğitimi ve Spor Bölümü

Tez Yöneticisi: Prof. Dr. Feza Korkusuz

Eylül 2009, 56 sayfa

Bu çalışmanın amacı genç futbolcularda dört hafta boyunca uygulanan solunum kası antrenmanın aralıklı toparlanma performansı solunum fonksiyonları ve maksimum oksijen kullanım kapasitesi (Vo_2max) üzerindeki etkilerini incelemektir. Çalışamaya Hacettepe Spor Kulübü'nden Turkiye PAF (Profeyonelliğe aday futbolcu hazırlık ligi) Ligi'nde oynayan ortalama 18.4 ± 0.8 yaş (17-19), 8.5 ± 0.7 (7-9) futbol deneyimi ve haftalık 120 MET değerlerine yıl sahip onsekiz genç futbol oyuncusu katılmıştır. Katılımcıların maxsimum oksijen kullanım kapasitesi (Vo_2max) koşu bandına entegre edilmiş gaz analizörü, solunum fonksiyonları spirometre ve toparlanma performansları ise Yo-yo aralıklı toparlanma seviye 2 testi ile ölçülmüştür. Daha sonra ise onsekiz katılımcı rasgele olarak solunum kası antrenmanı (RMT) (n = 9) veya kontrol (n = 9) grubu olarak ikiye ayrılmıştır. RMT grubundaki katılımcılar hem kendi olağan antrenmanlarına ve ayrıca ticari olarak satılan powerlung sport model (Powerlung Inc., TX, and USA) solunum kası antrenmanı cihazı ile dört hafta boyunca solunum kası antrenmanı (haftada 5 gün, günde iki kere 30 tekrar) yapmışlardır. Diğer yandan, kontrol grubundaki katılımcılar ise sadece kendi olağan antrenmanlarına devam etmişlerdir. Dört haftalık solunum kası antrenman periyodununun ardından solunum kası antrenmanının genç futbolcularda Vo_2max, solunum fonksiyonları (VC, FVC, $FEV_{1.0}$, and PEF) üzerindeki etkilerini görebilmek için aynı testler tekrar edilmiştir. Çalışmanın bulgularına göre, uygulanan dört haftalık solunum kası antrenmanı, kontrol grubundaki katılımcılar ile karşılaştırıldığında RMT grubundaki katılımcıların yo-yo aralıklı toparlanma seviye 2 testinde gerçekleştirdikleri toparlanma performanslarını istatistiksel olarak anlamlı (% 39) bir şekilde arttırmıştır. Fakat, RMT ve kontrol grubunun maksimum oksijen tüketim kapasitesi (Vo_2max) ve solunum fonksiyonları (VC, FVC, $FEV_{1.0}$, and PEF) üzerinde istatistiksel olarak anlamlı bir gelişme yaratmamıştır. Sonuç olarak genç futbolcularda dört hafta boyunca uygulanan solunum kası antrenmanı toparlanma performansını önemli ölçüde geliştirmiştir.

Anahtar Kelimeler: Maksimum Oksijen Kullanım Kapasitesi (Vo2max), Solunum Kası Antrenmanı, Yo-yo Aralıklı Toparlanma Testi, Solunum Fonksiyonu, Genç Futbolcular

.

To My Family

ACKNOWLEDGMENTS

I would like to gratefully acknowledge the support of, Prof. Dr. Feza Korkusuz, for him intellectual support and encouragement, which made this study possible. I would also like to thank the members of examining committee, Prof. Dr. Ömer Geban, Assoc. Prof. Dr. Settar Koçak for their guidance and discussing me for the different aspects of the study. Thanks to Prof. Dr. Emin Ergen for his advices and providing me connection to the Hacettepe Sports Club.

I would like to express my special thanks to research assistants Özgür Çelik and Emre Ak for their help and friendship and guiding in the test applications. I wish to thank to research assistant Recep Ali Özdemir for helping me in statistical analysis. Thanks to METU Medical Center for their patient and allowance to use their facility, machinery and resources. I also wish to thanks to all the subjects who volunteered to participate in the study and Hacettepe Sports Club’s coaches Osman Işılar, Ahmet Canatan, Muharrem Canlı, and staff for their co-working and allowance to use their facility throughout the study. Thanks to Tem-Sem Ltd. and Powerlung Inc. for providing the respiratory muscle devices used in this study.

Finally, I am grateful to my parents; Şerafettin Ali Özgider, Jale Özgider, my brother; Cem Özgider and also Assist. Prof. Dr. Hüseyin Özden Yurdakul, Prof. Dr. A. Mete Tunçoku. I would like to thank them for their support, encouragement, prayers and belief in me.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

CHAPTER I

INTRODUCTION

Modern professional soccer is one of the most popular and extremely physically demanding sports in the world (Bangsbo, 1994; Hillis, 1998; Reilly et al., 2000; Stolen et al., 2005). Elite soccer players run approximately 10-12 km throughout the 90 minute duration of the game that is composed of sprints each lasting about 2 to 4 seconds and cruise for 30 to 90 seconds (Bangsbo et al., 1991; Mohr et al., 2003; Reilly et al., 1976; Reilly, 1996; Stolen et al., 2005).

Energy is generally produced by aerobic metabolism in a soccer game (Bangsbo, 1994b; Stolen et al., 2005). Although aerobic metabolism is the primary energy producer in soccer, the anaerobic system is enrolled to perform jumps, sprints, tackles and other sudden actions (Agnevik et al., 1970; Bangsbo et al., 1991; Ekblom, 1986; Withers et al., 1982; Wragg et al., 2000). Soccer players therefore should be able to produce high aerobic and anaerobic power, during the game (Reilly et al., 2000).

The breathing (respiratory) muscles which are composed of the diaphragm, external and internal intercostals, parasternal, sternomastoid, scalene, external and internal oblique and abdominal muscles (Figure 1.1), are the vital organ in mammals by which oxygen is delivered to the red blood cells and concomitantly carbon dioxide is removed and expelled into the environment and play crucial role during exercise (Ratnovsky et al, 2008; Amonette and Dupler, 2002). Since the athletes take thousands of breaths during the competition and similarly all other skeletal muscles, the respiratory muscles also need required amount of oxygen in order to work properly (Amonette and Dupler, 2002).

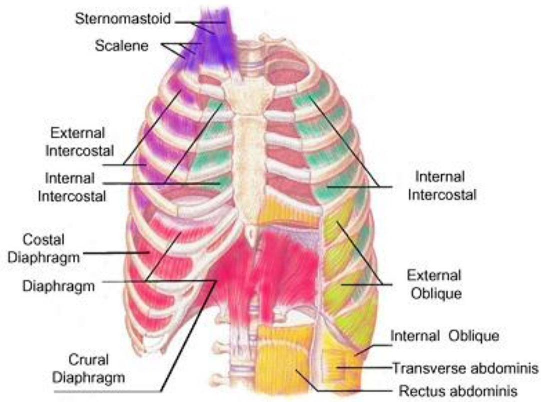


Figure1.1. Schematic description of the anatomy of human muscles
Source: (http://www.concept2.co.uk/training/breathing)

Formerly, it was widely known that the respiratory system does not limit the exercise performance in humans (Dempsey, 1986; Leith and Bradley 1976). However, many researchers stated that the respiratory system can impact the strength and exercise performance in healthy humans and highly trained athletes (Boutellier et al., 1992; Gething et al., 2004; Markov et al., 2001; Nicks et al., 2006; Stuessi et al., 2001; Suzuki et al., 1993; Volianitis et al., 2001), notably at high intensities (Harms et al., 2000; Wells et al., 2005).

Soccer is one of the intermittent sports that require high intensity bouts of exercise, with periods of passive or active recovery and coherent performance in repeated sprints need sufficient recovery between sprints (Nicks et al., 2006; Romer et al., 2002). During the high intensity exercise (sprints etc.), respiratory muscles (RM) are more active than at rest. For this reason RM need significant amounts of metabolic work in order to sustain effective respiration (Sheel, 2002). Decrease in blood flow to locomotor muscles and vasoconstriction are the fundamental outcomes of eminent amounts of RM work and fatigue of diaphragm (Gigliotti et al., 2006; Harms et al., 1997; Sheel, 2002; St Croix et al., 2000).

It was well established that skeletal muscles respond well to the resistance training when performed with straight scheme and load, this generate strength, specific muscle endurance and muscle hypertrophy (Amonette and Dupler, 2002; Baichle, 1994; Faulkner, 1985; Henrickson and Hickner, 1996). According to Pardy and his colleagues, (1988) just like all other skeletal muscles, the respiratory muscles' strength and endurance can be improved.

The respiratory muscle training (RMT) which has been extensively researched over past three decades, is used in order to increase the respiratory muscle function and prevent or delay the diaphragm fatigue that occurs throughout the high intensity exercise (Amonette and Dupler, 2002; Sheel, 2002; Spengler and Boutellier, 2000; Johnson et al., 1993). RMT may improve exercise capacity. Because, it delays or prevents the respiratory muscle fatigue (RMF) and its impact on blood flow redistribution moreover; increases the efficiency and induces the blood flow necessity of respiratory muscles along with the exercise (Gigliotti et al., 2006; Romer and Dempsey, 2004). Furthermore; decreases the vasoconstriction (Mostoufi et al., 1998; Somers et al., 1992).

There have been many studies conducted over for 30 years related to respiratory muscle training (RMT). Such studies can be separated mainly in two groups regarding their participants as with healthy humans (Enright et al., 2006; Gething et al., 2004; Gething et al., 2004; Romer and McConnell, 2003; Witt et al., 2007; Suzuki et al., 1993; Suzuki et al., 1995; Markov et al., 2001; Stuessi et al., 2001; McMahon et al., 2002), and athletes (Amonette and Dupler, 2002; Chatham et al., 1999; Fairbarn et al., 1991; Griffiths and McConnell, 2007; Guenette et al., 2006; Holm et al., 2004; Inbar et al., 2000; Johnson et al., 2007; Klusiewicz et al., 2008; Lindholm et al., 2007; Morgan et al., 1987; Nicks et al., 2006; Ray et al., 2008; Romer et al., 2002; Romer et al., 2002; Romer et al., 2002; Sonetti et al., 2001; Volianitis et al., 2001; Verges et al., 2007; Wells et al., 2005; Wylegala et al., 2007).

Although several studies stated that RMT caused improvement in exercise performance and pulmonary functions, some studies claimed that RMT did not affect the performance and ventilatory functions. Since, most of the studies used small sample sizes and limited number of studies utilized convenient control and or placebo groups (Sheel, 2002). Major portion of the mechanisms that underlying the improvements in exercise performance are still unknown and controversial issue (Boutellier, 1998; Gigliotti et al., 2006; Holm et al., 2004; Sheel, 2002; Spengler and Boutellier, 2000). However, little is known about the possible effect of RMT on during short term, high intensity intermittent exercise, because the athletes' recovery time attenuated in a prior study (Nicks et al., 2006).

In the present study, our general purpose was to determine the effects of respiratory muscle training on pulmonary functions and recovery performance of young soccer players.

1.1 Significance of the Study

Studies carried out in the area of RMT mainly have been focused on endurance activities (i.e. rowing, cycling, etc.) and increased time trial performance has been found (Romer et al., 2002; Volianitis et al., 2001). Only one study published about the soccer and respiratory muscle training (Nicks et al., 2006). Therefore, this study was significant by determining the effects of respiratory muscle training on pulmonary functions and intermittent recovery performance of young soccer players from the Haccettepe Sports Club PAF Team. Since, RMT would positively affect the soccer players' performance and would be strengthen the previous RMT studies' results. Furthermore, this investigation would highlight the importance of RMT as an ergogenic aid in intermittent sports and may open a gateway for further studies in this area (i.e. football, basketball, rugby etc.).

1.2 Hypothesis

There will be significant improvement in the intermittent recovery performance and pulmonary functions (VC, FVC, $FEV_{1.0}$, PEF) of young soccer players after a 4 week RMT.

1.3 Purpose of the Study

The purpose of this study was;

To determine the effects of a 4 week respiratory muscle training (RMT) on young soccer players' intermittent recovery performance, pulmonary functions, and maximum oxygen consumption capacity (VO_2max).

1.4 Definition of Terms

<u>Aerobic Metabolism:</u> The producing of energy (ATP) through the combustion of carbohydrates and fats in the presence of oxygen.

Anaerobic Metabolism: The producing of energy (ATP) through the combustion of carbohydrates in the absence of oxygen.

Concurrent: Performing at the same time.

COPD: Chronic obstructive pulmonary disease which refers to chronic bronchitis and emphysema, a pair of two commonly co-existing diseases of the lungs in which the airways become narrowed.

Diurnal Effect: The behavior of a human that is active in the daytime.

Exhalation: The movement of air out of the bronchial tubes, through the airways, to the external environment during breathing.

Force Vital Capacity (FVC): The maximum volume of air that a person can exhale after maximum inhalation.

Hypertrophy: One of the two most common and visible forms of organ hypertrophy occurs in skeletal muscles in response to strength training (known as muscle hypertrophy).

Inhalation: The movement of air from the external environment, through the air ways, and into the alveoli.

Intermittent Sports: Kind of sports in which movements start and stop regularly (i.e. soccer, basketball, rugby etc.).

Locomotor Muscles: The skeletal muscles that are mainly used for body movement.

Placebo: A sham (fake) medical intervention.

Pulmonary: Pertaining to the lungs and respiratory system.

Respiratory Muscles (RM): Composed of the diaphragm, external and internal intercostals, parasternal, sternomastoid, scalene, external and internal oblique and abdominal muscles.

Respiratory Muscle Training (RMT): Kind of training in order to improve the strength and endurance of the respiratory muscles by means of pressure-threshold device.

Spirometer: An apparatus for measuring the volume of air inspired and expired by the lungs.

Skeletal Muscles: Skeletal muscles which move and support the skeleton.

Tackles: Kind of football movement in order to stop dispossess an opponent of the ball or to stop the player from gaining ground towards goals

Vasoconstriction: Narrowing of the blood vessels resulting from contracting of the muscular wall of the vessels.

Ventilatory: Pertaining to the lungs and respiratory system.

1.5 Limitations of the Study

1. Only male soccer players were evaluated in this study.
2. A small sample size was measured because of the lack of availability of homogenous group of young soccer players in Ankara.
3. The participants were from a single football club.

1.6 Assumptions of the Study

1. It is assumed that the participants of the study understood the purpose of the study.
2. Participants presented their best performance throughout the tests.
3. The subjects followed and performed all pre-test instructions properly.
4. All the participants attended this study were homogenous.
5. The instruments which were used in this study were accurate and calibrated. The Middle East Technical University Medical Center in which the measurements were obtained has an ISO 9001: 2000 certificate and all instruments are regularly calibrated by the TSE (Turkish Standard Institute).

CHAPTER II

LITERATURE REVIEW

The Purpose of this chapter is to review previously investigated studies about respiratory, inspiratory and expiratory muscle training and their effects on athletes' performance that perform different sports moreover, other relevant studies.

Nicks and his friends (2006) investigated the effects of respiratory muscle training (RMT) on performance, dyspnea and respiratory muscle fatigue in intermittent sprint athletes. 27 (20 male, 7 female) collegiate soccer athletes participated in this study and they divided into two groups as RMT and control group. RMT group both continued their regular training and did 5 weeks RMT training, which composed of two session per day, 5 days per week and each session had 3 sets of inhalations by using powerlung sport device (Powerlung Inc., Houston, TX, USA) on the other hand the control group only did their regular training during the intervention period. The yo-yo intermittent recovery level 1 test (IRT) was used to asses the performance of the participants, dyspnea and respiratory muscle fatigue (RMF) was measured after the completion of IRT. Main finding of this study was the performance improved about 17 % in the RMT group. It was concluded that RMT improves performance and respiratory muscle strength in intermittent sprint athletes.

Enright and his colleagues (2006) conducted a study about the effect of high intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. In this study 20 (9 male, 11 female) moderately trained participants assigned to training and control groups. The training group did 8 weeks of inspiratory muscle training (IMT) consist of 36 repetitions and three times weekly by means of a pressure manometer with special computer software and the control group did not involve any physical training. Measurements included body composition, pulmonary function, and diaphragm thickness tests. This study stated that IMT generates improvements in inspiratory muscle function in the diaphragm thickness, lung volumes and also in the exercise capacity.

In the year 2007 Griffiths & McConnell examined the influence of inspiratory and expiratory muscle training upon rowing performance Seventeen male oarsmen were separated as inspiratory muscle training (IMT) (n =10) and expiratory muscle training (EMT) (n = 7) groups and they completed 4 week IMT or RMT training program and after that they performed 6 week joint training program (IMT / EMT) by utilizing two commercially available devices (POWERbreathe®, Gaiam, UK and Powerlung Inc., TX, USA) 30 inspiratory or expiratory inhalations twice a day. Measurements, which was composed of respiratory muscle strength, oxygen uptake, incremental rowing ergometer test, heart rate and blood lactate performed at 4^{th} and 10^{th} week of the training programs. According the main findings of this study IMT increased the rowing performance. However, EMT and combined IMT / EMT did not change significant differences.

The effects of respiratory muscle training (RMT) on VO_2max, the ventilatory threshold and pulmonary function was evaluated by Amonette and Dupler (2002). Twelve competitive triathletes and marathon runners was allocated to treatment (n = 8) and control (n = 4) groups and in the treatment group, participants underwent respiratory muscle training 30 inhalation twice a day throughout the 4 weeks by powerlung device (Powerlung Inc., TX, USA). On the other hand, subjects in the control group used the sham device at the same period of time. However, it had only 15 % resistance. Before and after the treatment maximum oxygen consumption (VO_2max) and pulmonary function measurements were implemented. The results of this study indicated that RMT increased the strength of the respiratory muscles. On the contrary, RMT did not improve the VO_2max.

In the year 2001 Volianitis and his co-workers stated that inspiratory muscle training improves rowing performance. The aim of this study was to evaluate the effects of resistive inspiratory muscle training (IMT) on rowing performance. 14 female competitive oarsmen were divided into to groups as IMT and both groups performed the same training program except in the control group subjects used the sham device which had 15 % resistance. Before and end of 11 week of IMT treatment by using power breathe device (POWERbreathe®, Gaiam, UK). The subjects were tested including rowing ergometer, maximum inspiratory pressure (MIP) respiratory muscle fatigue (RMF) and blood lactate tests were implemented. According to results of the study IMT improved the inspiratory muscle strength and rowing performance.

Guenette and his friends (2006) investigated the variable effects of respiratory muscle training (RMT) on cycle exercise performance in men and women. The aim of this study was to determine the effect of RMT on cycling time to exhaustion (TTE) and to clarify the gender effect. Fifteen participants as seven male and eight female performed incremental cycle test to measure maximum oxygen consumption (VO_2max), spirometry and maximal inspiratory pressure (MIP) measurements were taken prior to RMT program which was composed of 5 days of week, 30 repetitions twice a day, along with 5 weeks by using powerlung device (Powerlung Inc., TX, USA). After implementation of 5 weeks RMT program tests repeated to clarify effects of RMT program on selected parameters. RMT increased the MIP and might improve the cycle exercise performance were the main findings of the study. It was also found that there were no differences between male and female subjects.

Another study carried out by Wells et al. (2005) was the effects of concurrent inspiratory and expiratory muscle training on respiratory and exercise performance in competitive swimmers. 34 young competitive swimmers assigned into two groups as treatment (n = 17) and sham group (n = 17). They were asked to perform 12 weeks of concurrent inspiratory and expiratory muscle training (CRMT) 10 sessions per week by utilizing powerlung device. (Powerlung Inc., TX, USA). Moreover; they continued their regular swimming training. Participants' swimming performance, pulmonary functions, respiratory muscle strength and respiratory chemoreflex assessments were actualized before and after the implementation RMT. It was concluded that 12 weeks of RMT program significantly improved the dynamic pulmonary functions and breathing power.

Morgan and his colleagues (1987) studied the effects of respiratory muscle endurance training (RMET) on ventilatory and endurance performance of moderately trained cyclists. Nine male moderately cyclists divided into two groups as experimental (n = 4) and control (n = 5) prior to 3 weeks of ventilatory training program maximum oxygen consumption (VO_2max) test was performed on a cycle ergometer, and also ventilation tests were done. The test repeated after the 3 weeks ventilatory training program. The results of this study revealed that RMET did not change the VO_2max and cycling time. However, ventilatory power and endurance improved in the experimental group.

Inspiratory resistive loading (IRL) improves cycling capacity: a placebo controlled trial was investigated by Gething and his co-workers (2004) The objective of this study was to determine the effects of 10 week (three days a week) IRL treatment on ventilatory muscle performance and exercise endurance. 15 healthy subjects were separated to 3 groups as treatment (n = 5), sham group (n = 5), and control group (n = 5). Subjects' maximum oxygen consumption on a cycle ergometer (VO_2max) and lung functions were measured before the commencement of the IRL treatment and tests repeated after the 10 week of IRL implementation. The main findings of the study were the IRL treatment improved the cycling time to exhaustion and decreased the heart rate of the participants.

In the year 2007 Witt and his co-workers indicated that inspiratory muscle training attenuates the human respiratory muscle metaboreflex. The purpose of this study was to elicit the effects of 5 week inspiratory muscle training (IMT) which consisted of 6 days per week, once a day, and three sets of 75 repetitions by powerlung device (Powerlung Inc., TX, USA), on heart rate (HR) and mean arterial pressure (MAP). Prior to implementation of IMT treatment, sixteen participants assigned into two groups as experimental or sham control group and their respiratory muscle strength, HR, and MAP were tested during the resistive breathing task (RBT). After the intervention of 5 week IMT treatment, tests were repeated to see the effects of IMT training in both experimental and sham control groups. The results revealed that the inspiratory muscle strength improved and the time-dependent rise in HR and MAP decreased during the RBT following 5 weeks of IMT in the experimental group.

Inspiratory muscle fatigue in trained cyclists: effects of inspiratory muscle training (IMT) was examined by Romer et al. (2002) The goal of this study was to discover the effect of 20 and 40 km cycling time trials and IMT followed by post exercise inspiratory muscle function. Sixteen male competitive cyclists allocated to either treatment or sham control groups. Before the commencement of IMT treatment, pulmonary function, inspiratory muscle function, incremental exercise, and time trial performance tests were performed. Afterwards the same tests repeated to determine the differences. IMT training protocol consisted of 30 repetitions two times a day for six week by using powerbreathe device (POWERbreathe®, Gaiam, UK). The main findings of the study were following six week IMT treatment, both time-trial distances induced inspiratory muscle fatigue and the grade of this fatigue decreased. Besides, there were significant developments in 20 and 40 km time trial performance in experimental group.

Suzuki and his friends (1993) researched the inspiratory muscle training (IMT) and respiratory sensation during treadmill exercise. In this study they aimed to determine whether IMT change the respiratory sensation throughout the exercise. There were twelve healthy female participants in this stud and they were separated to two groups as experimental (n = 6) and control group (n = 6). Prior to implementation of IMT treatment that was composed of 15 minutes twice daily along with 4 weeks by threshold pressure breathing device (Threshold Inspiratory Muscle Trainer, Healthscan Products Inc., Cedar Grove, NJ), participants' lung volumes, pulmonary functions, maximal inspiratory pressure (PImax), maximal expiratory pressure (PEmax), maximal transdiaphragamatic pressure (Pdimax) and breathing effort on a treadmill were measured. Following the IMT treatment, tests performed again. Results showed that the Pdimax, PImax and PEmax strength increased. However, 4 weeks of IMT treatment had no effect on respiratory sensation during exercise.

In another study Romer and Mcconnell (2003) investigated the specificity and reversibility of inspiratory muscle training. Their purpose was to examine the pressure-flow specificity of adaptations to inspiratory muscle training (IMT). They worked on twenty four healthy participants and assigned them into four groups as low-flow-high pressure IMT (A), high-flow-low-pressure IMT (B), intermediate flow-pressure IMT (C), and no IMT or control. (D). Each training group performed IMT two times a day, 6 days of week throughout the nine weeks by using powerbreathe pressure-threshold device (POWERbreathe®, Gaiam, UK). Before the application of 9 week IMT treatment, pulmonary and maximum dynamic inspiratory muscle function were measured. The same tests repeated after 9 week of IMT treatment completed and also18 week post IMT. According to the results of this study it was indicated that the largest increase in pressure was observed in group A, group B had the largest improvement in flow, group C had regular increase in both pressure and flow and group D had no changes neither in pressure or flow. Furthermore, maximum inspiratory muscle power improved in all experimental groups (A, B, C). It was concluded that notion of the pressure-flow specificity of IMT was strengthened.

Klusiewicz et al. (2008) researched the inspiratory muscle training (IMT) in elite rowers. The aim of this investigation was to clarify the influence of the resistive IMT in elite male rowers. They studied on fifteen male oarsmen and divided them into two groups as control and experimental. Prior to 11 week of IMT consisted of 30 inhalations twice a day by using powerbreathe pressure-threshold device (POWERbreathe®, Gaiam, UK) participants' maximal inspiratory pressure (PImax) and maximum oxygen consumption (VO_2max) were measured on a rowing ergometer. After completing 11 week of IMT tests performed again. PImax significantly increased in the experimental group was the main finding of the study. It was concluded that IMT does not produce significant additional load for rowers and increase in respiratory muscles can be observed after 6 weeks.

Markov and his colleagues (2001) stated that respiratory muscle training (RMT) increases cycling endurance without affecting cardiovascular responses to exercise. In this study they aimed to see whether cycling endurance increased after RMT in thirty eight healthy sedentary subjects. The subjects allocated to either RMT (n = 15), an endurance training (ET, n = 10) or a control group (C, n = 15). Lung functions, maximum oxygen consumption (VO_2max) on a cycle ergometer and maximum aerobic power (Wmax) were assessed prior to and after the fifteen week of RMT comprised 40 sessions and each session lasted 30 minutes with selfdeveloped device. It was indicated 15 weeks of RMT improved the cycling and respiratory endurance but not to VO_2max.

Respiratory muscle endurance training in humans increase cycling endurance without affecting blood gas concentrations was studied by Stuessi and his friends (2001). Twenty eight healthy sedentary participants were divided into as either control (n = 13) or experimental group (n = 15). Before and following the implementation of 15 week of respiratory muscle training (RMT) which was composed of 40 repetitions with the duration of 30 minutes daily, participants' pulmonary functions (VC, $FEV_{1.0}$, PEF and MVV), maximum oxygen consumption (VO_2max) and maximum aerobic power (Wmax) on a cycle ergometer were measured. According to results of this investigation, fifteen week of IMT was improved the breathing and cycling endurance.

Chatham and hi co-workers (1999) stated that inspiratory muscle training (IMT) improves shuttle run performance in healthy subjects. In this study their purpose was to evaluate the use of pc-generated fixed-load incremental respiratory muscle training (RMT) in twenty two healthy participants. They were assigned to two groups either as experimental or control group. Both groups performed three tests of incremental respiratory endurance (TIRE) sessions at the 1st and 10th week of the study. The experimental group continued to perform RMT training throughout the 8 weeks. On the other hand the control group stopped to TIRE till 10th week of the study. Before and at the completion of the RMT implementation, subjects were measured with the multi stage fitness test (shuttle run) and after the completion of the shuttle run test their perceived exertion and predicted maximum oxygen consumption (VO_2max) were measured The results indicated that respiratory muscle strength (RMS), respiratory muscle endurance (RME), predicted VO_2 max and shuttle performance were improved in the experimental group.

In another study McMahon et al. (2002) specified that hyperpnea training attenuates peripheral chemosensitivity and improves cycling endurance. They studied on twenty trained male cyclists by assigning those two groups either as respiratory muscle training (RMT) or control group. Before and after the six week RMT implementation, participants' Spirometric (VC, FVC, $FEV_{1.0}$, PEF, and

MVV), breathing endurance, modified Dejours O_2, and the cycling endurance test were assessed. The results of the study were the peripheral chemoreceptor (pRc) response decreased, breathing endurance improved, maximum oxygen consumption (VO_2max) did not change, and finally the cycling endurance increased in the RMT group.

Effects of respiratory muscle training (RMT) versus placebo on endurance exercise performance were investigated by Sonetti and his friends (2001). Seventeen healthy competitive male cyclists participated in this study. In this research their objective was to evaluate the effects of 5 week RMT consisted of 5 sessions per week (total 25 sessions) via powerbreathe pressure-threshold device (POWERbreathe®, Gaiam, UK) on male cyclists. After the pre-tests subjects were divided into two groups as RMT and placebo control group. Prior to and after completing RMT treatment they were tested including; pulmonary function (VC, FVC, and $FEV_{1.0}$,), pressure, gas, flow, volume, respiratory muscle performance, cycling performance, and blood measurements. Maximal inspiratory pressure (PImax) increased in RMT group; both RMT and placebo groups' performance time in the fixed work rate test increased and the 8 km time trial performance improved in RMT group were the main findings of this study.

Another research carried out by Romer, McConnell, and Jones (2002) was the effects of inspiratory muscle training (IMT) on time-trial performance in trained cyclists. In this double blinded experimental study, sixteen trained male cyclists were separated either an experimental or placebo (sham-training control) group. Their maximum dynamic inspiratory muscle function, pulmonary function, and the perceptual and physiological responses to maximal incremental cycling were measured. Afterwards they were requested to perform 6 weeks IMT training (30 repetitions twice a day) by using powerbreathe pressure-threshold device (POWERbreathe®, Gaiam, UK). After the intervention of 6 week IMT completed tests performed again. According to results of the study; the dynamic inspiratory muscle function increased in the experimental group, perceptual response to maximal incremental exercise was decreased, and the experimental group completed the 20 and 40 km time trial faster than placebo group did.

In the year 2004 Holm and his colleagues implied that the endurance training of respiratory muscles improves cycling performance in fit young cyclists. In this research twenty experienced cyclists allocated to three groups as experimental (n = 10), the placebo (n = 4), and the control group (n = 6). After the respiratory muscle training (RMT) treatment, (20 sessions with the duration of 45 minutes) participants in the experimental group improved their endurance of respiratory muscles and pulmonary functions. Therefore, it was concluded that RMT increase cycling performance in cyclists.

Inbar, Weiner, Azgad, Rotstein, and Weinstein (2000) investigated the specific inspiratory muscle training (SIMT) in well-trained endurance athletes. In this study their objective was to determine the effectiveness of the IMT on development of respiratory muscle function and aerobic capacity in endurance athletes. Twenty well-trained endurance athletes were divided into two groups either experimental or sham control groups. They performed 10 weeks SIMT, 6 times per week with a threshold inspiratory muscle trainer (Threshold Inspiratory Muscle Trainer, Healthscan, NJ). Prior to and following 10 week of SIMT participants' pulmonary functions, respiratory muscle strength, inspiratory muscle endurance, and exercise capacity test on a treadmill were measured. The results revealed that in the experimental group inspiratory muscle strength (PImax) and inspiratory muscle endurance (PmPeak) improved significantly. They concluded that 10 week of SIMT can improve the inspiratory muscle performance in well-trained athletes.

Effect of respiratory muscle endurance training (RMET) on respiratory sensations, respiratory control and exercise performance was examined by Verges, Boutellier, Spengler (2008). One hundred and thirty-five healthy subjects were participated in this 15 year longitudinal research. 90 of them assigned to RMET group and 45 of them to control group. RMET training composed of 20 sessions of normocapnic hyperpnoea along with 4-5 weeks, each session lasted for 30 minutes except for the 21 subjects who were performed 8 or 13 weeks of RMET. Before and after the RMET intervention, participants were requested to perform some tests including; lung function, maximal pressures, respiratory endurance, incremental cycling, and cycling endurance tests. Results indicated that both cycling and respiratory endurance were improved, perception of breathlessness decreased. Lung functions were improved. Cycling time was also increased.

Johnson, Sharpe, and Brown (2007) stated that inspiratory muscle training (IMT) improves cycling time-trial performance and anaerobic work capacity but not critical power. The objective of this study was to evaluate the influence of IMT on cycling time trial performance. Eighteen male cyclists were allocated to either IMT or placebo control group. Participants were asked to perform IMT (30 repetitions twice daily throughout the 6 weeks) treatment with inspiratory pressure-threshold device (POWERbreathe®, Gaiam, UK). Before and the after intervention of 6 week IMT participants were tested including; pulmonary function, maximal inspiratory pressure (PImax), 25 km time-trial performance, and three constant-power tests. PImax, 25 km time-trial performance, and cycling endurance improved in experimental group after the completion of 6 weeks IMT were the main findings of this investigation.

Suzuki, Sato, and Okubo (1995) investigated the expiratory muscle training (EMT) and sensation of respiratory effort during exercise in normal subjects. Twelve healthy subjects were participated in this study and then they were assigned to two groups as experimental and control group. The subjects in the experimental group performed 4 weeks EMT treatment 15 minutes twice daily with a threshold pressure breathing device (Threshold Inspiratory Muscle Trainer, Healthscan Products, Cedar Grove, New Jersey, USA). At the beginning and end of the EMT treatment, participants were assessed including; maximum inspiratory and expiratory pressures (PImax and PEmax), respiratory effort by using Borg scale (Borg, 1987), and progressive exercise test on a treadmill. The results of the study showed that PEmax increased, minute ventilation and breathing frequency attenuated in the experimental group. It was concluded that EMT improves expiratory muscle strength.

Another study carried out by Fairbarn, Coutts, Pardy, and McKenzie (1991) was the improved respiratory muscle endurance of highly trained cyclists and the effects on maximal exercise performance. In this study they aimed to clarify the influence of respiratory muscle endurance (RME) training on exercise performance. Ten male trained male cyclists were separated to either experimental or control group. Maximal incremental test, respiratory muscle endurance, endurance cycle test, and pulmonary function tests were implemented before and after the RME treatment which was composed of total 16 sessions along with 3 or 4 weeks and each session had three 8 minutes. According the results of this study, 4 week RME training improved the respiratory muscle endurance but not the maximal cycling performance in cyclists.

The effects of different inspiratory muscle training intensities on exercising heart rate and perceived exertion was researched by Gething, Passfield, and Davies (2004). Sixty-six healthy participants (40 males, and 26 females) were attended in this study and they were divided into three groups as maximum inspiratory pressure (MIP), IMT, and control group. MAX group did 6 weeks 100 % MIP training, SUB group received 6 weeks IMT training, and on the other hand the control group did no training. Before and after the IMT intervention subjects' lung function including MIP, maximum expiratory pressure, forced vital capacity (FVC), forced expiratory volume in one second ($FEV_{1.0}$), peak expiratory flow (PEF), exercising heart rate (HR), and the rating of perceived exertion (RPE) were measured. MIP improved both in the MAX and SUB groups. HR and RPE attenuated in the MAX group were the main findings of this study.

Wylegala, Pendergast, Gosselin, Warkander, and Lundgren (2007) stated that respiratory muscle training (RMT) improves swimming endurance in divers. The aim of this study was to clarify the effectiveness of two different RMT on the swimming performance of swimmers. Thirty experienced swimmers were participated in this study. Prior to implementation of RMT all subjects were trained with fin along with 4 weeks (3 days of the week) and afterwards, their pulmonary function, maximum oxygen consumption (VO_2max), swimming endurance tests at the surface and underwater with SCUBA equipment were conducted. Participants were allocated to endurance (ERMT), a resistance (RRMT), or placebo (PRMT) groups and each of them underwent 4 weeks different RMT treatment. At the end of the 4 week RMT implementation the tests were repeated. The results of this study revealed RRMT and ERMT treatments improve respiratory muscle and underwater swimming performance.

In another research conducted by Ray and his friends (2008) implied that respiratory muscle training improves swimming endurance at depth. Nine experienced and certified male divers. The aim of this study was to evaluate the influence of resistive respiratory muscle training (RRMT) on endurance of swimming at depth and respiratory function. Before the study participants completed 4 week fin-training and respiratory muscle strength afterwards, maximal inspiratory and expiratory pressures (MIP and MEP), maximum oxygen consumption (VO_2max) at both surface and underwater, pulmonary function, underwater swimming endurance tests were implemented. They underwent RRMT treatment consisted of 30 minutes daily, 5 days week, throughout the 4 weeks and tests were performed again. According to the results of this investigation that RRMT improves the swimming performance both at depth and surface.

In the year 2007 Lindholm, Wylegala, Pendergast, and Lundgren stated that resistive respiratory muscle training (RRMT) improves and maintains endurance swimming performance in divers. They studied on twenty experienced SCUBA divers before the RRMT intervention; participants were requested to train themselves by 4 weeks fin training and then they were separated to either RRMT-3 (3 days per week) or RRMT-5 (5 days per week). Prior to and after RMT intervention, their pulmonary function, maximum oxygen consumption (VO_2max) during surface swimming, and swimming endurance at the surface and underwater were tested. The results revealed that both surface and depth fin swimming performance improved. They concluded that RRMT-3 or 5 days per week can be suggested to divers.

CHAPTER III

MATERIALS AND METHODS

VO_2 max, pulmonary and intermittent recovery performance measurements were performed at the Medical Center of the Middle East Technical University and Gençlerbirliği İlhan Cavcav Sport Complex.

3.1 Participants

Eighteen elite male young soccer players who were members of the Hacettepe Sports Club in Ankara participated in this study. They were playing in the Turkey PAF League (league for candidate professional soccer players) and all of them healthy who had no history of heart or lung disease that caused them to stop playing soccer. They were non-asthmatic, non-smokers and non-alcohol users. Their experience in soccer was 8.5 ± 0.7 (ranging from 7 to 9 years) and their weekly MET score was 120. All participants volunteered for this study. The exact nature of the studies' purpose was explained to subjects and informed consent was obtained on the possible risks and benefits of the experimental procedure. Ethical Committee approval was gathered from the Applied Ethics Research Center (UEAM) of Middle East Technical University. A personal information sheet was given to gather their experience in soccer.

3.2 Research Design

In this study an experimental design with a convenience sampling method were used. After the pre-tests participants were randomly assigned into either to respiratory muscle training group (RMT) or control group. In the RMT group participants both continued their regular training and 4 weeks Powerlung (Powerlung Inc., TX, USA) treatment; on the other hand, control group only continued their regular training and after 4 weeks of RMT training completed subjects were tested again to see whether there are any differences between the two groups.

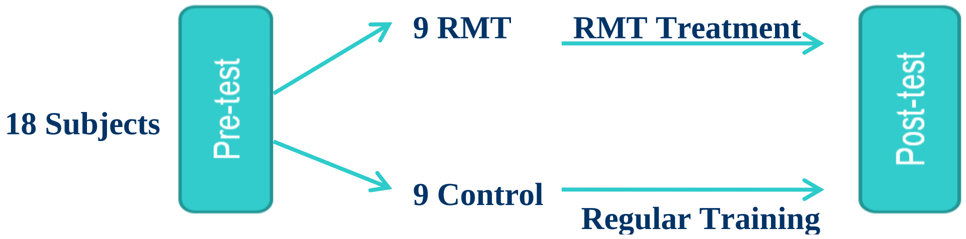


Figure 3.1 Scheme for the design of the study

3.3 Data Collection Procedures

Data were collected by the author at the end of the 2008-2009 seasons between the April and June. Before data collection, necessary permission was obtained from team managers and the coaches. Ethical Committee approval was gathered from the Applied Ethics Research Center (UEAM) of Middle East Technical University.

3.4 Collection of Personal Information

Body height was measured by a Seca 220 anthropometer (Hammer Steindamm 9-25 22089 Hamburg, Germany) as the head of the participant was on the frontal axis with the over-head board touching vertex point in centimeters. During the height measurements participants were barefoot. Body weight was assessed with the subject dressed only underpants with sensitive balance by Seca 220 beam-balance scale (Hammer Steindamm 9-25 22089 Hamburg, Germany) Body Mass Index (BMI) was calculated as the ratio of body weight in kilograms to the square of the standing body height in meters (kg/sq m).

$$\text{BMI} = \text{Body Weight (kg)} / \text{Body Height}^2 \text{ (m)}$$

3.5 Measurement of Intermittent Recovery Performance

In order to measure participants' intermittent recovery performance yo-yo intermittent recovery level 2 test (Yo-Yo IR2 test) was used. The test composed of repeated 20 x 20 m shuttle runs at a progressively increased velocity monitored by audio signals from an audio player. Between the each shuttle subjects had a 10 seconds active recovery phase with 5 x 5 m jogging. When the subjects failed to complete shuttle two times in time, the distance covered at that point is recorded and represented the test result. The test was implemented on outdoor artificial turf which was 2-m-wide and 20-m-long running lane marked by cones and another cone was placed 5 m behind of the finish line for the active recovery phase. Before the test all participants conducted warm-up and they were accustomed to the test one time (Krustrup et al., 2006). During the tests subjects' heart rate was measured by Polar Vantage NV heart rate monitor (Polar Electro Oy, Kempele, Finland).

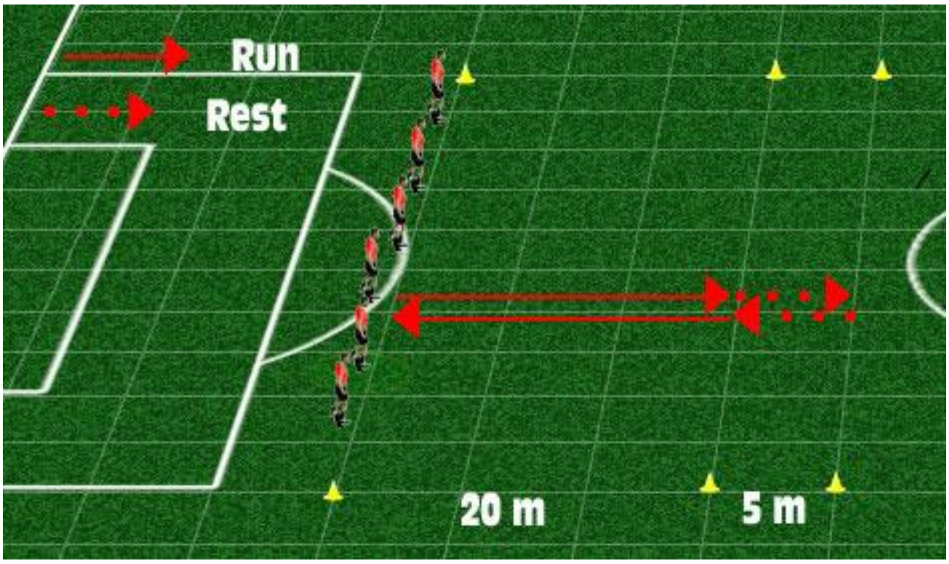


Figure 3.2 Yo-yo intermittent recovery test level 2

Source: (http://www.elitesoccerconditioning.com/images/yoyorecoverytest.jpg)

3.6 Measurement of Pulmonary Function

Vitalograph Alpha III Spirometer (Vitalograph, Inc., Lenexa, KS) was used in order to measure the vital capacity (VC) and forced vital capacity (FVC) of the participants. In the VC test participants were asked to exhale as long as they could from full inspiration. However, in the FVC test subjects asked to take the deepest breath they can, and then exhale into the sensor as hard as possible, for as long as possible directly followed by a rapid inhalation (Crapo et al., 1994). In both VC and FVC tests, participants sat on a chair with their nose was closed with a clip to make sure that no air escaped from the nose and they did 3 repetitions by clean mouthpiece for each test and the best one was recorded. Before the measurements they did not do any vigorous exercise (Clanton and Diaz, 1995).

Figure 3.3 Vitalograph Alpha III Spirometer

Source: (http://www.wms.co.uk/sharedimages/Large/W33734.jpg)

3.7 Measurement of Maximum Oxygen Consumption (VO_2max)

In order to determine participants' maximum oxygen consumption capacity Master Screen CPX Ergospirometry System on a treadmill Viasys LE 200 CE (Viasys Heathcare, Jaeger, Würzburg, Germany) was used. The Bruce Protocol was used in which the workload was increased by altering both the incline percent and velocity of the treadmill. Test started at speed 2,74km/hr and grade of 10% and it progressively increased at every 3 minutes until the participant exhausted (Bruce et al., 1973). During the test participant was breathed via a 2-way valve system. Air came in from the room, however expired through sensors that measure both oxygen concentration and volume. Polar Vantage NV heart rate monitor was used (Polar Electro Oy, Kempele, Finland) to measure the heart rate of the participants. 48 hours prior to measurements participants were asked not to participate in any vigorous exercise to avoid any possible diurnal effects (Vivian & Heyward 1998).

Figure 3.4 VO2 max testing on a treadmill

Source: (http://www.jaeger-toennies.com/english/products/cardio-respiratory/treadmill-ergometers/e-treadmill-ergometer.html

3.8 Respiratory Muscle Training (RMT)

Following the maximal tests, participants in the RMT group were requested to perform respiratory muscle training (RMT) composed of thrithy maximal inhalation / exhalation cycles each lasted 3 seconds two times daily, five days per week throughout the four weeks (total 20 training session) as prescribed by Powerlung manufacturers by using commercially available Powerlung sport training device

(Powerlung Inc., TX, USA). The RMT treatment performed before (30 repetitions) and after (30 repetitions) the participants' regular training under the supervision of their coach and the researcher. During the duration of the study participants were asked not to increase or decrease their training regimen.

Figure 3.5 Powerlung Sport (Powerlung Inc., TX, USA) respiratory muscle trainer device
Source: (http://www.powerlung.com/region/us/products/sports-fitness/sport)

3.9 Statistical Analysis of Data

The statistical program for social sciences version 15.0 (SPSS 10.0) was used for statistical analyses. Independent sample t-tests were used to check baseline equivalence among groups. Separate mixed design repeated measures ANOVAs with group as between subject factor were then used to determine the effects of pulmonary function training. Interpretation of the results was based both on statistical significance and effect sizes which indicate the magnitude of difference between groups. Effect size was considered as a useful measurement for evaluating the meaningfulness of statistical results when sample size is too large or too small (Sutlive & Ulrich, 1998). Eta-square (η^2) values were used to determine the practical significance of the differences. (η^2) Represents the proportion of total variance in dependent variable explained by independent variables. Specifically, (η^2) values between 0.01 - 0.03, 0.06 – 0.09, and > 0.14 indicate a small, medium and large effect, respectively (Cohen, 1988).

CHAPTER IV

RESULTS

4.1 Subject Characteristics

Eighteen active and highly trained soccer players from Hacettepe Sports Club PAF Team participated in this study. Their mean age was 18.4 ± 0.8 years (ranging from 17 to 19 years). The mean body weight was 71.0 ± 4.8 kg (ranging from 63 to 80 kg). The mean height was 1.78 ± .04 cm (ranging from 1.70 to 1.85 cm). The mean BMI (Body Mass Index) was 22.5 ± 1.2 kg / m² (ranging from 19.6 to 25.2 kg / m²). The mean year of experience in soccer was 8.5 ± 0.7 years (ranging from 7 to 9 years). After the pre-tests, participants were randomly assigned into two groups as either respiratory muscle training (RMT) or control group. In Table 4.1 characteristics of the participants were demonstrated. There were no statistically significant differences between the RMT and control groups in terms of physical characteristics of the participants.

Table 4.1 Physical Characteristics of the Subjects

Group	N	Age (Year)	Height (cm)	Weight (kg)	BMI (kg / m²)	Experience (Year)
RMT	9	18.4 ± 0.5	1.76 ± 0.5	69.6 ± 4.6	22.4 ± 0.9	8.6 ± 0.5
Control	9	18.3 ± 1	1.79 ± 0.3	72.3 ± 4.95	22.6 ± 1.5	8.4 ± 0.9

4.2 Baseline Comparisons

All subjects completed both pre and post-test measurements. Mean values of RMT and control groups in Yo-yo test, Vo_2max, vital capacity (VC), forced vital capacity (FVC), forced expiratory flow in one second ($FEV_{1.0}$), and peak expiratory flow (PEF) performances were given in Table 4.2. Separate independent t-tests were performed in order to check baseline equivalence of RMT and control groups.

Independent sample t-tests revealed that there was no significant difference between RMT and control groups in terms of Vo2max [t(16)=1.10, p>0.05], Yo-yo test [t(16)=0.50, p>0.05], VC [t(16)=0.48, p>0.05], FVC [t(16)=0.36, p>0.05], $FEV_{1.0}$ [t(16)= -.10, p>0.05], and PEF [t(16)=-1.12, p>0.05] performances (Table 4.3). Baseline comparisons confirmed that subjects were equally assigned to RMT and control conditions.

Table 4.2 Baseline Comparisons Between RMT and Control Groups.

	f	***t***	***df***	***p***
Vo_2max	0.69	1.10	16	0.28
Yo-yo Test	0.49	0.50	16	0.62
Vital Capacity	0.48	0.48	16	0.63
Forced Vital Capacity	2.90	0.36	16	0.72
Forced Expiratory Flow	0.15	-.10	16	0.89
Peak Expiratory Flow	0.56	-1.12	16	0.27

4.3 Effects of respiratory muscle training on pulmonary functions and intermittent recovery performance

Separate repeated measures ANOVAs were conducted to examine effects of respiratory muscle training on Vo2max, Yo-yo test, VC, FVC, $FEV_{1.0}$ and PEF performances. A 2 (Time: pre-test, post-test) x 2 (Group: treatment, control) repeated measure ANOVA for Vo2max performances revealed that there was no significant main effects of time [F(1,16)= 1.83, p>0.05, $\eta^{2=}$.10, power=.24], group [F(1,16)= 1.85, p>0.05, $\eta^{2=}$.10, power=.25], and group*time interaction [F(1,16)= 0.69, p>0.05, $\eta^{2=}$.01, power=.07] (Figure 1). η^2 values indicated medium effect for time and group analyses and a small effect for group*time interaction. However, there was a significant main effect of time [F(1,16)= 35.15, p<0.05, $\eta^{2=}$.69, power=1.00], group [F(1,16)= 4.65, p<0.05, $\eta^{2=}$.23, power=.53] and group*time interaction [F(1,16)= 21.45, p<0.05, $\eta^{2=}$.58, power=.99] (Figure 2) on yo-yo test performances. Pairwise comparisons with adjusted alpha levels (**α=.**025) indicated that compared to subjects in the control group, subjects in the RMT group significantly improved their yo-yo test performances from pre to post test measurements. Checking the η^2 values also indicated large effect for time, group and group*time interaction analyses.

Considering the VC performances results showed although that there was a significant main effect of time [F(1,16)= 10.16, p<0.05, $\eta^{2=}$.38, power=.85], both main effect of group [F(1,16)= 0.14, p>0.05, $\eta^{2=}$.01, power=0.06] and group*time interaction [F(1,16)= 0.20, p>0.05, $\eta^{2=}$.01, power=.07] were not significant (Figure 3). η^2 values indicated large effect for time, but small effect for group and group*time interaction. Throughout the 4 week period both RMT and control group increased their VC performances and there was no significant difference between RMT and control group from pre to post measurements. In accordance with the VC performances, repeated measures ANOVA results for the FVC yielded that there was significant main effect of time [F(1,16)= 24.25, p<0.05, $\eta^{2=}$.60, power=.99]. However, no significant main effect for group [F(1,16)= 0.08, p>0.05, $\eta^{2=}$.01, power=.06] and group*time interaction [F(1,16)= 0.26, p>0.05, $\eta^{2=}$.02, power=.08] were found (Figure 4). η^2 values indicated large effect for time, but small effect for group and group*time interaction. Throughout the 4 week period both RMT and control group increased their FVC performances and there was no significant difference between RMT and control group from pre to post measurements.

When $FEV_{1.0}$ performances were taken into account results revealed that although there was a significant main effect of time [F(1,16)= 8.19, p<0.05, $\eta^{2=}$.34, power=.77], both main effect of group [F(1,16)= 0.04, p>0.05, $\eta^{2=}$.00, power=0.01] and group*time interaction [F(1,16)= 0.31, p>0.05, $\eta^{2=}$.01, power=.05] were not significant (Figure 5). η^2 values indicated large effect for time, but small effect for group and group*time interaction. Throughout the 4 week period both RMT and control group increased their $FEV_{1.0}$ performances and there was no significant difference between RMT and control group from pre to post measurements. In accordance with the $FEV_{1.0}$ performances, repeated measures ANOVA results for the PEF performances yielded that there was significant main effect of time [F(1,16)= 19.90, p<0.05, $\eta^{2=}$.55, power=.98]. However, no significant main effect for group [F(1,16)= 0.11, p>0.05, $\eta^{2=}$.01, power=.07] and group*time interaction [F(1,16)=

0.90, $p>0.05$, $\eta^2=.06$, power=.16] were found (Figure 6). η^2 values indicated large effect for time, medium effect for group and small effect for the group*time interaction analyses. Throughout the 4 week period both RMT and control group increased their PEF performances and there was no significant difference between RMT and control group from pre to post measurements.

Table 4.3 Pre-test and Post-test Values of RMT and Control Groups for Dependent Variables.

	Groups							
	RMT (n=9)				**Control (n=9)**			
	Pre test		**Post test**		**Pre test**		**Post test**	
Measurements	$\bar{x}$	**SS**	$\bar{x}$	**SS**	$\bar{x}$	**SS**	$\bar{x}$	**SS**
Yo-Yo Test	16.4	3.4	22.8*	3.8	15.5	4.1	16.3	3.9
VO_2max	58.6	2.6	57.6	2.3	56.6	4.6	54.7	6.7
Vital Capacity	4.6	0.7	4.8	0.4	4.4	0.7	4.8	0.6
Forced Vital Capacity	4.4	0.6	4.9	0.5	4.2	0.8	4.7	0.6
Forced Expiratory Flow	3.5	0.6	3.9	0.4	3.6	0.5	3.9	0.7
Peak Expiratory Flow	267.3	70.4	354.7	79.8	309.3	86.6	384.1	100.8

*p<.05.

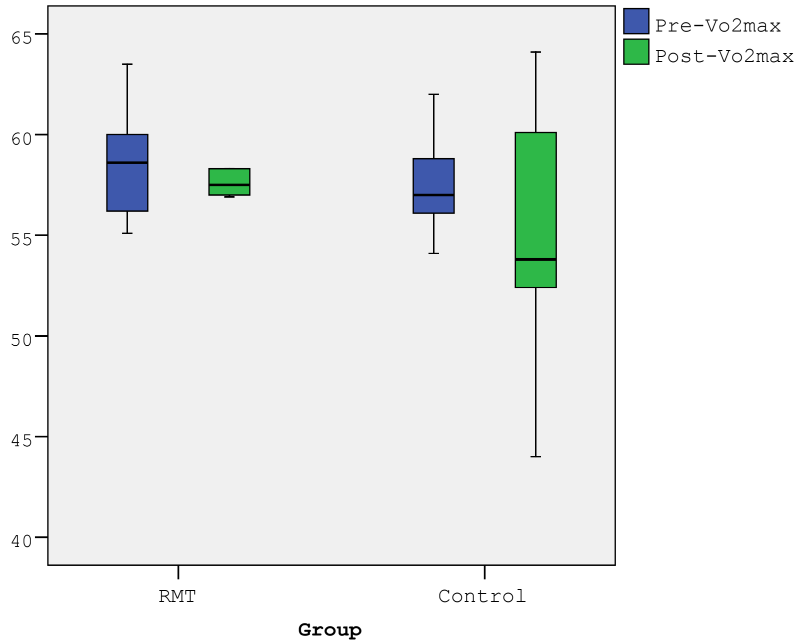


Figure 4.1 There were No Significant Changes in VO_2max Capacity between the RMT and Control Groups from Pre to Post-test Measurements.

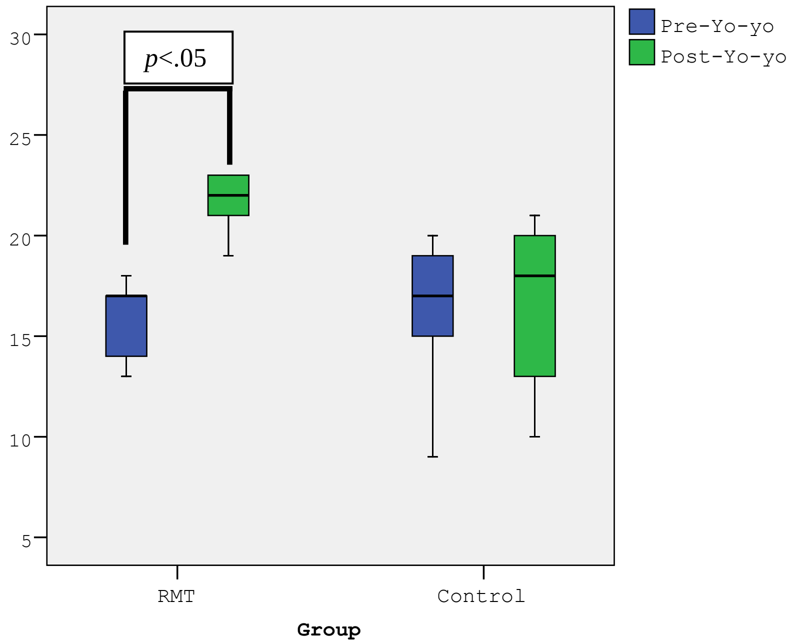


Figure 4.2 There were Significant Improvements in Intermittent Recovery Performance between the RMT and Control Groups from Pre to Post-test Measurements.

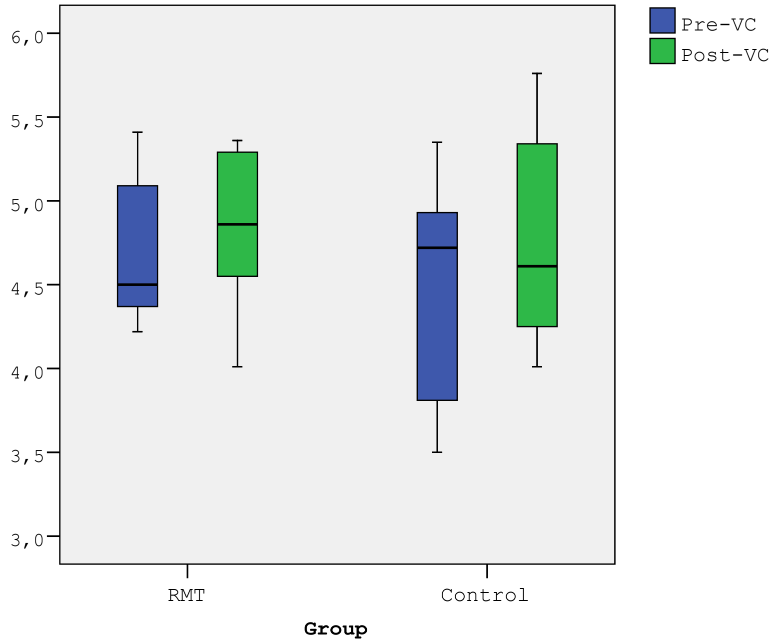


Figure 4.3 There were No Significant Changes in VC Performance between the RMT and Control Groups from Pre to Post-test Measurements.

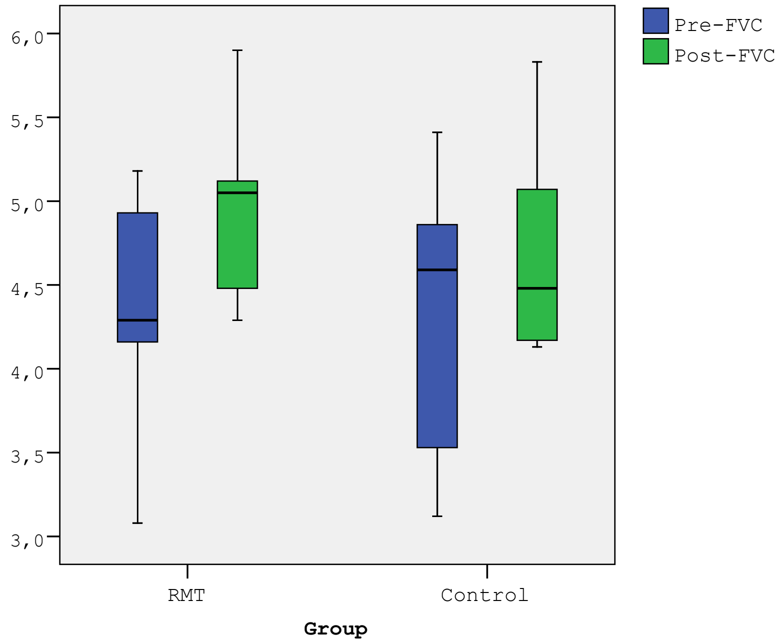


Figure 4.4 There were No Significant Changes in FVC Performance between the RMT and Control Groups from Pre to Post-test Measurements.

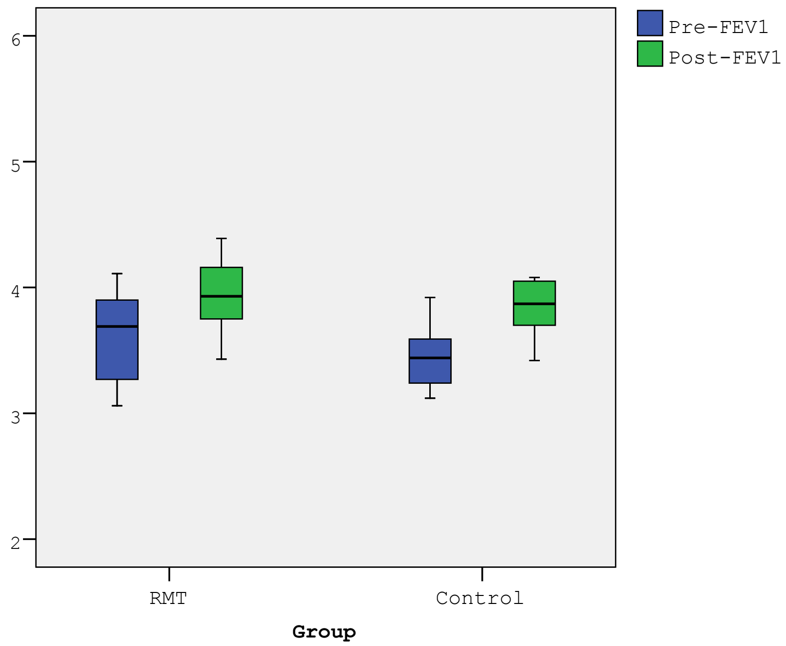


Figure 4.5 There were No Significant Changes in $FEV_{1.0}$ Performance between the RMT and Control Groups from Pre to Post-test Measurements.

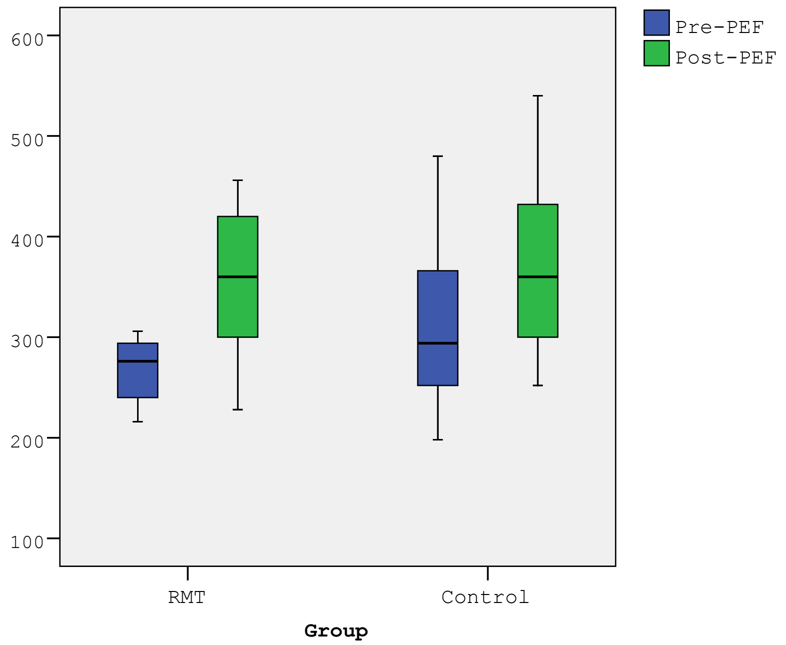


Figure 4.6 There were No Significant Changes in PEF Performance between the RMT and Control Groups from Pre to Post-test Measurements.

CHAPTER V

DISCUSSION

There have been many studies conducted about the topic of respiratory muscle training (RMT). However, they were mainly related to endurance activities (i.e. cycling, rowing, running etc.) and there is insufficient literature on soccer. Because of this gap in the literature, the main purpose in the present study was to clarify the 4 week RMT effect on pulmonary function, recovery performance and maximum oxygen consumption capacity (VO2max) of young soccer players. Results of the present study were discussed in the framework of recovery performance, pulmonary functions, VO_2max capacity, 4 week RMT treatment and the two groups of active young soccer players.

In order to investigate the effectiveness of 4 week RMT treatment, participants were requested to perform RMT for 4 weeks. There were eighteen elite young soccer players randomly separated to two groups as either RMT group (n = 9) or control group (n = 9). The main findings of the present study indicated that the intermittent recovery performance of the RMT group significantly improved after 4 week RMT implementation when compared to the control group. VO_2max capacity slightly decreased in both groups. Although there were improvements in VC, FVC, $FEV_{1.0}$ and PEF performances in both groups throughout the 4 week RMT period, there were no group and group*time interactions. In other words, VC, FVC, $FEV_{1.0}$, PEF performances improved in the RMT group, however they were not significant when compared to the control group. Therefore, these improvements in pulmonary functions might be attributed to participants' habitual training regimens.

There were several limitations of this study. Firstly, the lactate levels of the participants were not measured. Instead, the yo-yo intermittent recovery test level 2 was used in order to assess the recovery performance of the participants. Secondly, the participation ratio of the subjects' regular training was followed during the period of the study by the information that was obtained from their coaches and managers. A small sample size was used due to the limitation of the instruments. Moreover, the maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) that are the good indicators of respiratory muscle strength (Gething et al., 2004; Guenette et al., 2006) was not assessed in this study. A sedentary group in which the participants did not attend any regular physical activities could have been added this study in order to see the effects of RMT on sedentary people.

There was a significant improvement in the intermittent recovery performance in the RMT group when compared to the control group (% 39). Parallel to our study, Nicks and his colleagues (2006) observed a significant improvement in intermittent recovery performance (16.7 % ± 17.2 %) with RMT. Observing the similar results in intermittent recovery performance may have been related to the either using the same RMT device Powerlung Sport Model (Powerlung Inc., TX, USA) or to applying the almost same RMT period and regimen. Besides, no significant improvements were observed in both the control and the RMT groups in terms of FVC and $FEV_{1.0}$ performances that study. However, they observed a significant improvement in maximal inspiratory pressure (PImax) that was not evaluated in our study. Male young soccer players were only assessed in our study. On the contrary, Nicks et al. evaluated both male and female collegiate soccer players (20 male, 7 female). In addition to this, although VO_2max capacity of the participants was measured in our study, it was not expected that there would be significant improvements in VO_2max capacity. It might be the result of the short duration of RMT treatment (i.e. 4 weeks).

Our study was in agreement with that of Romer et al., (2002) in terms of the similar improvements in recovery time after inspiratory muscle training. In addition, like in the Romer’s investigation VO_2max capacity of the participants did not change significantly in the present study. Thus, it is possible to say that the changes in VO_2max capacity might not be ascribed to the RMT training. In the same way FVC, FEV_1, PEF, performances of the participants did not change significantly. On the other hand, MIP and PIF performances which did not measured in this investigation, of the participants in the experimental group improved significantly in Romer’s study. Different from current study, they also measured blood lactate level of the participants and found a significant attenuation. Actually this attenuation in blood lactate level might be an evidence for improvement in exercise and recovery performance capacity in intermittent sports caused by RMT treatment. Because RMT may delay or increase accessory muscle function which leads to development in breathing efficiency and therefore less energy consumption for breathing and supplying blood to the locomotor muscles (Boutellier, 1998; Dempsey, 1986; Johnson et al., 1996; Romer et al., 2002). If the blood lactate level of the participants measured in reigning investigation there would be the same decreasements in this parameter. Since, the similar improvements were observed in intermittent recovery performance.

Similar to the current investigation, Chatham and his colleagues (1999) also found a significant improvement in the shuttle run performance after eight week inspiratory muscle training (IMT). In the present study, a slight decrease was observed in both groups' VO_2max capacity. Conversely, they observed an increase in the VO_2max capacity in the RMT group. The reason to explain this finding might be a longer period of RMT treatment. In other words, the longer periods of RMT treatment may increase VO_2max capacity. In our study, assessment was made at 4 weeks of training and time dependent improvement was not assessed Secondly, Chathams worked with healthy participants who involved only in recreational activities. Highly trained young soccer players whose VO_2max capacity already high participated in our study. Significant changes in VO_2max capacity in highly trained athletes are rarely observed in a short period and such changes are generally the result of high levels of aerobic training in a long duration. Therefore, a major improvement in VO_2max capacity was not anticipated in our study. Furthermore, the present study was conducted two months prior to the ending of the PAF league that might be another reason for the slight decrease in VO_2max capacity. In that sense, we may say that working with the non-athletes and using longer periods of RMT treatment might be the reason for improvements in the VO_2max capacity.

Findings of this investigation were also in a consistency with another research carried out by Amonette & Dupler (2002) in which they did not see any improvement in the VO_2max capacity. This consistency could have been the results of using the same RMT device, approximately similar RMT training regimen, duration and the congruency of the participants in terms of their high physical condition in both studies. Besides, the improvements in VO_2max capacity scarcely seen in short periods and results of a high levels of aerobic training in an over baguette term (Amonette & Dupler, 2002). They also did not find any alterations in ventilatory functions. That may be due to the participants' high physical condition (i.e. ceiling effect) since they had already trained their respiration muscles. Furthermore, a short duration of RMT training might be another reason for this finding.

In the current study significant changes in VC, FVC, $FEV_{1.0}$ and PEF performances were not observed. Parallel to the present study, Boutellier et al. (1992) also did not find changes in $FEV_{1.0}$ and PEF performances. This might be caused by the highly trained athletes who were used in both studies and the short duration of RMT (i.e. 4 weeks). Besides, FVC and other pulmonary functions mainly controlled by individuals' stature and not affected by training. Thus, these improvements in the pulmonary functions may be explained by familiarization to the spirometer device (Gething et al., 2004). In addition to this, as participants were adolescent athletes (17 to 19 years) in the current study, it is feasible that growth might have been one of the factors in the observed improvements in pulmonary functions. However, the duration of the study (i.e. 4 week) was short relatively and could not affect the results (Wells et al., 2005). Furthermore; spirometer has not a resistance like in the powerlung RMT device. Thus, it may be another cause that while blowing into spirometer during pulmonary function testing was not like blowing into a powerlung device. As a result of this, spirometry assessments might not alter before and after 4 week of RMT treatment.

As mentioned before, there were no significant improvements in pulmonary functions (VC, FVC, $FEV_{1.0}$ and PEF) when compared to control groups. There might be some reasons that affect the results. One of them, could be small sample size (n = 18) used in this study. Another reason might be that spirometer had no resistance contrary to RMT training devices. Concerning one of the main purposes of the current study was to determining the effectiveness of 4 week RMT training on intermittent recovery performance. Yo-yo intermittent recovery test level 2 was used (Bangsbo et al., 2008; Krusturup et al., 2003; Krusturup et al., 2006) in order to assess the participants' ability to recover from repeated exercise (i.e. recovery performance). According to results of the present study, 4 week RMT treatment improved the recovery performance of young male soccer players. The important reason for observing significant results in intermittent recovery performance could be the using the right test (Yo-yo intermittent recovery test level 2) to evaluate this parameter. Since, the football (soccer) is an intermittent sport in its nature that players do not run constantly and the performance is associated to athlete's capacity to repeatedly perform high intensity bouts of exercise (Bangsbo et al., 1991; Ekblom, 1986; Mohr & Bangsbo, 2001).

Laboratory performance tests in which the participants perform activities (rowing, running, cycling, walking etc.) constantly are seen as controversial. Because in the real game, athletes alter their speed and should cope with environmental issues (hill, sun, wind etc.) and these tests do not imitate the competitive circumstances. (Guenette et al., 2005; McLellan et al., 1995; Sheel, 2001) In the present study a fixed load running protocol (Bruce et al., 1973) on a treadmill was utilized in order to measure the VO_2max capacity of the participants. Although, the time performance in the constant treadmill running protocol test was not a parameter evaluated in this study, it did not change significantly before and after 4 week RMT implementation. However, the yo-yo intermittent recovery test level 2 reflects the real game conditions than laboratory test (Bangsbo et al., 2008; Krusturup et al., 2003; Krusturup et al., 2006). Since, intermittent recovery performance was improved in a present study. It indicates the effectiveness of RMT treatment on recovery performance. In the same way, while measuring the pulmonary functions only three maximal measurements were performed for pulmonary variables (i.e. VC, FVC, $FEV_{1.0}$ and PEF) and the best one recorded as data. In other words, pulmonary measurements were performed like in the constant load treadmill measurements in this study. If pulmonary function assessments were performed similar to intermittent recovery test level 2 (i.e. repetitively) there might be significant improvements in some pulmonary functions that analogous to recovery performance improvements in RMT group when compared to control group. Because, depending on the results of this investigation. The respiratory muscles also may have recovery ability same as the other skeletal muscles.

In the present study, highly conditioned participants were evaluated similar to several investigations carried out in the RMT area (Amonette et al., 2002; Enright et al., 2006; Fairbarn et al., 1990; Griffiths et al., 2007; Holm et al., 2004; Inbar et al., 1999; Johnson et al., 2007; Klusiewicz et al., 2008; Lindholm et al., 2007; McMahon et al., 2002; Morgan et al., 1987; Nicks et al., 2006; Ray et al., 2008; Romer et al., 2002; Romer et al, 2002; Romer et al, 2002; Sonetti et al., 2001; Volianitis et al., 2001; Wells et al., 2005; Wylegala et al., 2007). Using well trained athletes may generate an ideal circumstance to control the test to Powerlung Sport RMT device (Powerlung Inc., TX, USA). Since, the athletes that evaluated in this study already had high physiological traits, any alterations or improvements in the selected parameters (pulmonary functions, intermittent recovery performance) in the current investigation could be attributed to the 4 week of RMT treatment.

In general, the effectiveness of RMT training on exercise performance has been a divisive issue. Because the conducted investigations mainly employed various laboratory exercise performance tests, different training regimens (duration, repetition of RMT treatment etc.) and RMT devices moreover, divergent kind of participants (patients, athletes, sedentary etc.) who had different physical state. In addition to this, the majority of the studies have used small sample sizes (Sheel, 2001). Furthermore, the mechanism by which RMT increases general exercise and recovery performance is still unknown (Boutellier, 1998; Gigliotti et al., 2006; Inbar et al., 1999; Romer et al., 2002; Sonetti et al., 2001; Spengler&Boutellier, 2000; Sheel, 2001; Witt et al., 2007).

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

This chapter includes the conclusions related to this and recommendations for the further investigations.

6.1 Conclusions

The main results of this study indicated that 4 week respiratory muscle training (RMT) improves the intermittent recovery performance in highly trained young soccer players. However, there were no significant improvements in VO_2max capacity, vital capacity, (VC), forced vital capacity (FVC), forced expiratory flow in one second ($FEV_{1.0}$) and peak expiratory flow (PEF) performances. These results of present study support previous evidence that respiratory muscle improves the intermittent recovery performance. In other words, this study provides new evidence of intermittent recovery performance enhancements in young soccer players after RMT treatment.

6.2 Future Recommendations

1) Well controlled further studies are required in this topic in order to explain the physiological mechanisms by which alterations in respiratory muscle function improve intermittent recovery performance.

2) While conducting RMT studies, more parameters of pulmonary functions need to be rigorously investigated than in the current study.

3) Larger sample sizes are needed and also the gender issue can be taking into consideration.

4) Not to use well trained athletes are important in order to see the effect of RMT more clearly in future studies. Since, the well-trained athletes are already train their pulmonary muscle etc.

5) In order to determine which RMT treatment affects the performance better. Implementation of various kind of RMT treatment with longer periods than performed in present study may be another recommendation for further investigations.

REFERENCES

Agnevik, G. (1970). editor. Fotboll. Idrottsfysiologi, *Rapport no. 7. Stockholm*: Trygg-Hansa.

Amonette, W., & Dupler, T. (2002). The effects of respiratory muscle training on VO2 max, the vantilatory thresold and pulmonary function. *Journal of Exercise Physiology, 5* (2), 29-35.

Baichle, TR. ed (1994). Essentials of strength and conditioning. *Human Kinetics Campaign.*

Bangsbo, J. (1994b). The physiology of soccer-with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica, 15* (suppl. 619), 1-156.

Bangsbo, J. (1994). The physiology of soccer--with special reference to intense intermittent exercise. *Acta Physiologica Scandinavica. Supplementum*, *619*, 1-155.

Bangsbo, J., Nørregaard, L., & Thorsø, F. (1991). Activity profile of competition soccer. *Canadian Journal of Sport Sciences = Journal Canadien Des Sciences Du Sport, 16*(2), 110-116.

Bruce, A., Kusumi, F., & Hosmer, D. (1973). Maximal oxygen intake and nomographic assessment of funtional aerobic impairment in cardiovascular disease. *American Heart Journal* 85, 546-562

Boutellier, U. (1998). Respiratory muscle fitness and exercise endurance in healthy humans. *Medicine and Science in Sports and Exercise, 30*(7), 1169-1172.

Boutellier, U., Büchel, R., Kundert, A., & Spengler, C. (1992). The respiratory system as an exercise limiting factor in normal trained subjects. *European*

Journal of Applied Physiology and Occupational Physiology, *65*(4), 347-353.

Boutellier, U., & Piwko, P. (1992). The respiratory system as an exercise limiting factor in normal sedentary subjects. *European Journal of Applied Physiology and Occupational Physiology*, *64*(2), 145-152.

Chatham, K., Baldwin, J., Griffiths, H., Summers, L., & Enright, S. (1999). Inspiratory muscle training improves shuttle run performance in healthy subjects. *Physiotherapy 85*, 676-683.

Clanton, T. L., & Diaz, P. T. (1995). Clinical assessment of the respiratory muscles. *Physical Therapy*, *75*(11), 983-995.

Cohen, J. (1988). Statistical analysis for the behavioral sciences (2nd ed.). *Hillsdale, Nj*. Lawrance Erlbaum.

Crapo, R.O. (1994). Pulmonary-function testing. *N. Engl. J. Med*. 331, 25-30.

Dempsey, J. A. (1986). J.B. Wolffe memorial lecture. Is the lung built for exercise? *Medicine and Science in Sports and Exercise*, *18*(2), 143-155.

Ekblom, B. (1986). Applied physiology of soccer. *Sports Med. Jan-Feb 3* (1), 50-60.

Enright, S. J., Unnithan, V. B., Heward, C., Withnall, L., & Davies, D. H. (2006). Effect of high-intensity inspiratory muscle training on lung volumes, diaphragm thickness, and exercise capacity in subjects who are healthy. *Physical Therapy*, *86*(3), 345-354.

Fairbarn, M. S., Coutts, K. C., Pardy, R. L., & McKenzie, D. C. (1991). Improved respiratory muscle endurance of highly trained cyclists and the effects on maximal exercise performance. *International Journal of Sports Medicine*, *12*(1), 66-70.

Faulkner, JA. (1985). Structural and functional adaptations of skeletal muscle in: Roussos, C., and Macklem, PT (eds) *The Thorax Part B*, Marcel Dekker, New York, 1329-51.

Gething, A. D., Passfield, L., & Davies, B. (2004). The effects of different inspiratory muscle training intensities on exercising heart rate and perceived exertion. *European Journal of Applied Physiology*, *92*(1-2), 50-55. doi: 10.1007/s00421-004-1044-2.

Gething, A. D., Williams, M., & Davies, B. (2004). Inspiratory resistive loading improves cycling capacity: a placebo controlled trial. *British Journal of Sports Medicine*, *38*(6), 730-736. doi: 10.1136/bjsm.2003.007518.

Gigliotti, F., Binazzi, B., & Scano, G. (2006). Does training of respiratory muscles affect exercise performance in healthy subjects? *Respiratory Medicine*, *100*(6), 1117-1120. doi: 10.1016/j.rmed.2005.09.022.

Griffiths, L. A., & McConnell, A. K. (2007). The influence of inspiratory and expiratory muscle training upon rowing performance. *European Journal of Applied Physiology*, *99*(5), 457-466. doi: 10.1007/s00421-006-0367-6.

Guenette, J. A., Martens, A. M., Lee, A. L., Tyler, G. D., Richards, J. C., Foster, G. E., et al. (2006). Variable effects of respiratory muscle training on cycle exercise performance in men and women. *Applied Physiology, Nutrition, and Metabolism = Physiologie Appliquée, Nutrition Et Métabolisme*, *31*(2), 159-166. doi: 10.1139/h05-016.

Harms, C. A., Babcock, M. A., McClaran, S. R., Pegelow, D. F., Nickele, G. A., Nelson, W. B., et al. (1997). Respiratory muscle work compromises leg blood flow during maximal exercise. *Journal of Applied Physiology (Bethesda, Md.: 1985)*, *82*(5), 1573-1583.

Harms, C. A., Wetter, T. J., St Croix, C. M., Pegelow, D. F., & Dempsey, J. A. (2000). Effects of respiratory muscle work on exercise performance. *Journal* *of Applied Physiology (Bethesda, Md.: 1985)*, *89*(1), 131-138.

Henrickson, J., & and Hickner, RC. (1996). Training induced adaptations in skeletal muscle in: Harries, M., Williams, C., Stanish, WD., & Micheli, LJ. (eds) *Textbook of Sports Medicine*, Oxford University Press, New York, 27-45.

Heyward, V. (1998). Advanced fitness assessment & exercise prescription 3rd edition *Human Kinetics Publishers*.

Hillis, S. (1998). Preparations for the World Cup. *British Journal of Sports Medicine*, 32, 95.

Holm, P., Sattler, A., & Fregosi, R. F. (2004). Endurance training of respiratory muscles improves cycling performance in fit young cyclists. *BMC Physiology*, *4*, 9. doi: 10.1186/1472-6793-4-9.

Inbar, O., Weiner, P., Azgad, Y., Rotstein, A., & Weinstein, Y. (2000). Specific inspiratory muscle training in well-trained endurance athletes. *Medicine and Science in Sports and Exercise*, *32*(7), 1233-1237.

Johnson, B. D., Babcock, M. A., Suman, O. E., & Dempsey, J. A. (1993). Exercise-induced diaphragmatic fatigue in healthy humans. *The Journal of Physiology*, *460*, 385–405.

Johnson, M. A., Sharpe, G. R., & Brown, P. I. (2007). Inspiratory muscle training improves cycling time-trial performance and anaerobic work capacity but not critical power. *European Journal of Applied Physiology*, *101*(6), 761-770. doi: 10.1007/s00421-007-0551-3.

Klusiewicz, A., Borkowski, L., Zdanowicz, R., Boros, P., & Wesołowski, S. (2008). The inspiratory muscle training in elite rowers. *The Journal of Sports Medicine and Physical Fitness*, *48*(3), 279-284.

Leith, D. E., & Bradley, M. (1976). Ventilatory muscle strength and endurance training. *Journal of Applied Physiology, 41*(4), 508-516.

Lindholm, P., Wylegala, J., Pendergast, D. R., & Lundgren, C. E. G. (2007). Resistive respiratory muscle training improves and maintains endurance swimming performance in divers. *Undersea & Hyperbaric Medicine: Journal of the Undersea and Hyperbaric Medical Society, Inc, 34*(3), 169-180.

Markov, G., Spengler, C. M., Knöpfli-Lenzin, C., Stuessi, C., & Boutellier, U. (2001). Respiratory muscle training increases cycling endurance without affecting cardiovascular responses to exercise. *European Journal of Applied Physiology, 85*(3-4), 233-239.

McLellan TM, Cheung SS, Jacobs I., Variability of time to exhaustion during submaximal exercise. *Can J Appl Physiol*, 1995; 20 (1), 39-51.

McMahon, M. E., Boutellier, U., Smith, R. M., & Spengler, C. M. (2002). Hyperpnea training attenuates peripheral chemosensitivity and improves cycling endurance. *J Exp Biol, 205*(24), 3937-3943.

Mohr, M., & Bangsbo, J. (2001) Development of fatigue towards the end of a high level soccer match. *Med. Sci. Spots Exerc*. 33, 215.

Mohr, M., Krustrup, P., & Bangsbo, J. (2003). Match performance of high-standard soccer players with special reference to development of fatigue. *Journal of Sports Sciences, 21*(7), 519-528.

Morgan, D. W., Kohrt, W. M., Bates, B. J., & Skinner, J. S. (1987). Effects of respiratory muscle endurance training on ventilatory and endurance performance of moderately trained cyclists. *International Journal of Sports Medicine*, *8*(2), 88-93.

Mostoufi-Moab, S., Widmaier, E. J., Cornett, J. A., Gray, K., & Sinoway, L. I. (1998). Forearm training reduces the exercise pressor reflex during ischemic rhythmic handgrip. *J Appl Physiol, 84*(1), 277-283.

Nicks, C., Farley, R., Fuller, D., Morgan, D., & Caputo, J. (2006). The effect of respiratory muscle training on performance, dyspnea, and respiratory muscle fatigue in intermittent sprint athletes. *Medicine & Science in Sports & Exercise. 38 (5)*, 381.

Pardy, RL., Reid, WD., & Belman, MJ. (1988). Respiratory muscle training. *Clin Chest Med.9*, 287–96.

Ratnovsky, A., Elad, D., & Halpern, P. (2008). Mechanics of respiratory muscles. *Respiratory Physiology & Neurobiology*, *163*(1-3), 82-89. doi: 10.1016/j.resp.2008.04.019.

Ray, A. D., Pendergast, D. R., & Lundgren, C. E. G. (2008). Respiratory muscle training improves swimming endurance at depth. *Undersea & Hyperbaric Medicine: Journal of the Undersea and Hyperbaric Medical Society, Inc, 35*(3), 185-196.

Reilly, T., & Thomas, V. (1976). A motion analysis of work rate in different positional roles in professional football match-play. *J Hum Mov Stud 2*, 87-97.

Reilly, T. (1990). Football (Soccer). T, Reilly., N, Secher., P, Snell., & C, Williams. eds. *Physiology of Sports (1st edition)*. London: E & FN Spon. pp. 371–401.

Reilly, T. (1996). Motion analysis and physiological demands. T Reilly, ed. *Science and Soccer*. London: E & FN Spon. pp. 65–81.

Reilly, T., Bangsbo, J., & Franks, A. (2000). Anthropometric and physiological predispositions for elite soccer. *Journal of Sports Sciences*, *18*(9), 669-683.

Romer, L. M., McConnell, A. K., & Jones, D. A. (2002). Effects of inspiratory muscle training upon recovery time during high intensity, repetitive sprint activity. *International Journal of Sports Medicine*, *23*(5), 353-360. doi:

10.1055/s-2002-33143.

Romer, L. M., & McConnell, A. K. (2003). Specificity and reversibility of inspiratory muscle training. *Medicine and Science in Sports and Exercise*, *35*(2), 237-244. doi: 10.1249/01.MSS.0000048642.58419.1E.

Romer, L. M., McConnell, A. K., & Jones, D. A. (2002a). Inspiratory muscle fatigue in trained cyclists: effects of inspiratory muscle training. *Medicine and Science in Sports and Exercise*, *34*(5), 785-792.

Romer, L. M., McConnell, A. K., & Jones, D. A. (2002b). Effects of inspiratory muscle training on time-trial performance in trained cyclists. *Journal of Sports Sciences*, *20*(7), 547-562.

Romer, LM., & Dempsey, JA. (2004). The work of breathing during exercise: implications for performance. In: Aliverti, A., Brusasco, V., Macklem, PT., & Pedotti A, editors. Mechanics of breathing: pathophysiology, diagnosis and treatment. *Milano, Springer.*

Sheel, A. W. (2002). Respiratory muscle training in healthy individuals: physiological rationale and implications for exercise performance. *Sports Medicine (Auckland, N.Z.)*, *32*(9), 567-581.

Somers, V. K., Leo, K. C., Shields, R., Clary, M., & Mark, A. L. (1992). Forearm endurance training attenuates sympathetic nerve response to isometric handgrip in normal humans. *J Appl Physiol*, *72*(3), 1039-1043.

Sonetti, D. A., Wetter, T. J., Pegelow, D. F., & Dempsey, J. A. (2001). Effects of respiratory muscle training versus placebo on endurance exercise performance. *Respiration Physiology*, *127*(2-3), 185-199.

Spengler, C. M., & Boutellier, U. (2000). Breathless Legs? Consider Training Your Respiration. *News in Physiological Sciences: An International Journal of Physiology Produced Jointly by the International Union of Physiological*

Sciences and the American Physiological Society, *15*, 101-105.

St Croix, C. M., Morgan, B. J., Wetter, T. J., & Dempsey, J. A. (2000). Fatiguing inspiratory muscle work causes reflex sympathetic activation in humans. *The Journal of Physiology*, *529 Pt 2*, 493-504.

Stølen, T., Chamari, K., Castagna, C., & Wisløff, U. (2005). Physiology of soccer: an update. *Sports Medicine (Auckland, N.Z.)*, *35*(6), 501-536.

Stuessi, C., Spengler, C. M., Knöpfli-Lenzin, C., Markov, G., & Boutellier, U. (2001). Respiratory muscle endurance training in humans increases cycling endurance without affecting blood gas concentrations. *European Journal of Applied Physiology*, *84*(6), 582-586.

Sutlive,V., & Ulrich, D. (1998). Intrepreting statistical significance and meaningfulness in adapted physical activity research. *Adapted Physical Activity Quarterly 15*, 103-118.

Suzuki, S., Sato, M., & Okubo, T. (1995). Expiratory muscle training and sensation of respiratory effort during exercise in normal subjects. *Thorax*, *50*(4), 366-370.

Suzuki, S., Yoshiike, Y., Suzuki, M., Akahori, T., Hasegawa, A., & Okubo, T. (1993). Inspiratory muscle training and respiratory sensation during treadmill exercise. *Chest*, *104*(1), 197-202.

Verges, S., Boutellier, U., & Spengler, C. M. (2008). Effect of respiratory muscle endurance training on respiratory sensations, respiratory control and exercise performance: a 15-year experience. *Respiratory Physiology & Neurobiology*, *161*(1), 16-22. doi: 10.1016/j.resp.2007.11.004.

Verges, S., Lenherr, O., Haner, A. C., Schulz, C., & Spengler, C. M. (2007). Increased fatigue resistance of respiratory muscles during exercise after respiratory muscle endurance training. *American Journal of Physiology.*

Regulatory, Integrative and Comparative Physiology, 292(3), R1246-1253. doi: 10.1152/ajpregu.00409.2006.

Volianitis, S., McConnell, A. K., Koutedakis, Y., McNaughton, L., Backx, K., & Jones, D. A. (2001). Inspiratory muscle training improves rowing performance. *Medicine and Science in Sports and Exercise, 33*(5), 803-809.

Wells, G. D., Plyley, M., Thomas, S., Goodman, L., & Duffin, J. (2005). Effects of concurrent inspiratory and expiratory muscle training on respiratory and exercise performance in competitive swimmers. *European Journal of Applied Physiology, 94*(5-6), 527-540. doi: 10.1007/s00421-005-1375-7.

Witt, J. D., Guenette, J. A., Rupert, J. L., McKenzie, D. C., & Sheel, A. W. (2007). Inspiratory muscle training attenuates the human respiratory muscle metaboreflex. *The Journal of Physiology, 584*(Pt 3), 1019–1028. doi: 10.1113/jphysiol.2007.140855.

Withers, RT., Maricic, Z., & Wasilewski, S., et al. (1982). Match analysis of Australian professional soccer players. *J Hum Mov Stud 8,* 159-76.

Wragg, C. B., Maxwell, N. S., & Doust, J. H. (2000). Evaluation of the reliability and validity of a soccer-specific field test of repeated sprint ability. *European Journal of Applied Physiology, 83*(1), 77-83.

Wylegala, J. A., Pendergast, D. R., Gosselin, L. E., Warkander, D. E., & Lundgren, C. E. G. (2007). Respiratory muscle training improves swimming endurance in divers. *European Journal of Applied Physiology, 99*(4), 393-404. doi: 10.1007/s00421-006-0359-6.

APPENDICES

APPENDIX A

PULMONARY FUNCTION ASSESSMENT SHEET

VITALOGRAPH - ALPHA

TARIH 28/ 6/09

ISIM: ....

SIRA NO: 43

YAS: 18

BOY: 173 CM.

CINSIYET: ERKEK

ETNIK KOKEN: KAFKASYALI HARICI

REFERANS DEGERLER: ERS 93

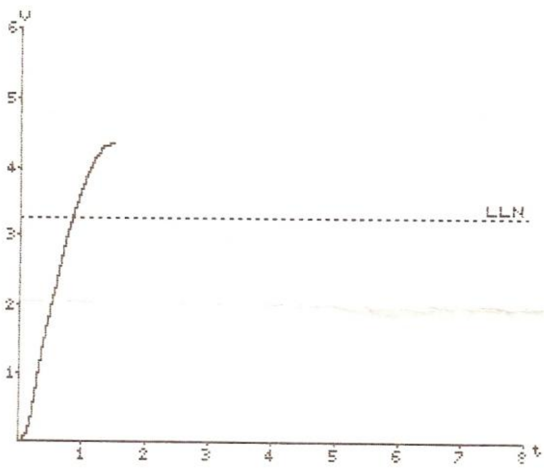
YAZILIM REF.NO: 61217 ISSUE 3

KALIBRASYON YENILEME TARIHI: 1/ 9/20

KALIBRASYON KONTROL TARIHI : 16/ 8/02

3 TESTLER, EN IYI ARALIK 4%

	PRED.	MEAS.	%
VC	4.42	4.57	103
IVC	4.42	3.85	87
FVC	4.23	4.37	103
FEV1	3.59	4.06	113
FEV1 %	83	89	6
PEF	582	378	65
FEF25-75	4.98	4.12	83
FEF25	8.25	5.90	72
FEF50	5.43	4.40	81
FEF75	2.53	3.00	119
FIF25	4.82	3.50	73
FIF50	5.35	3.40	64
FIF75	4.50	3.50	78
PIF	6.98	4.30	62
MVV IND	131	152	117



APPENDIX B

INFORMED CONSENT FORM

Gönüllü Katılım (Bilgilendirilmiş Onay) Formu

Sayın Katılımcı,

Bu çalışma O.D.T.Ü. Beden Eğitimi ve Spor Bölümü Araştırma Görevlisi Can ÖZGİDER'in Prof. Dr. Feza KORKUSUZ (O.D.T.Ü. Eğitim Fakültesi, Beden Eğitimi ve Spor Bölümü) tarafından yürütülen "Genç *Futbolcularda 4 haftalık solunum kası antrenmanının toparlanma performansı ve solunum fonksiyonlarına etkileri* " başlıklı araştırma projesidir. Çalışmanın amacı genç futbolcularda 4 haftalık solunum kası antrenmanın toparlanma performansı ve solunum fonksiyonlarına olan etkilerini ortaya çıkartmaktır.

Araştırmada sizden istenecek olan, çalışamaya katılacak olan diğer futbolcularla ile birlikte haftada 5 gün, günde iki kere "Powerlung Sport Solunum Kası Geliştirici" ile 4 haftalık solunum kası antrenmanını araştırmacı eşliğinde uygulamaktır. Ayrıca 4 haftalık solunum kası antrenmanının başlangıcından önce ve sonrasında yapılacak olan treadmill maksimum oksijen kullanımı testi (VO_2max), spirometre testi ve yo-yo aralıklı toparlanma seviye 2 testine katılmaktır. Testler ortalama 1.5-2 saat sürecektir. Çalışmada herhangi bir rahatsızlık veya stres beklenmemektedir. Ancak performans testlerinde biraz zorlanma hissedilebilir.

Çalışmaya katılım zorunlu değildir. Herhangi bir sebep belirtmeksizin ve herhangi bir yaptırım olmaksızın araştırmada yer almaktan vazgeçebilirsiniz. İlgili bilgilerin şahsınıza aktarılmasını, araştırma kayıtlarıdan silinmesini veya tamamen yok edilmesini isteyebilirsiniz. Çalışmada herhangi bir risk beklenmemektedir. Katılımımn sonuçları güvenilir olacaktır elde tüm bilgiler gizli tutulacaktır ve bilimsel yayımlarda kullanılacaktır. Kayıt edilen bütün veriler araştırmacı tarafından 3 yıl Orta Doğu Teknik Üniversitesinde saklı tutulacak ve daha sonra yok edilecektir.

Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Beden Eğitimi ve Spor Bölümü öğretim üyelerinden Prof. Dr. Feza KORKUSUZ (Oda: 401 Tel: 0312 210 40 16; e-posta: feza@metu.edu.tr) ya da araştırma görevlisi Can ÖZGİDER (Oda: 409 Tel: 0312 210 40 22; e-posta: ozgider@metu.edu.tr) ile iletişim kurabilirsiniz.

Bu çalışmaya tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Ad Soyad Tarih İmza ----/----/-----

APPENDIX C

PERSONAL INFORMATION SHEET

PERSONAL INFORMATION SHEET

ODTÜ BESB ve SRM ANKET FORMU

Sayın katılımcı, lütfen aşağıdaki soruları cevaplayınız.
Katılımcının

Adı : .... Soyadı: ……………………
Tel(İş): ………………………… Yaşı: ………………………
Tel(Ev): ……………………….. Boy: ………………………
Tel(Cep): ……………………… Kilo: ……………………...
Adres: ………………………… Cinsiyeti: ………………….
e-mail: …………………………

1- Sizde ve ailenizde (anne-baba-kardeş) herhangi bir sistematik bir hastalığı (şeker, yüksek tansiyon, kalp veya damar problemi v.b.) olan var mı?

□ Evet, bende …………………………. hastalığı var.
□ Evet, bende …………………………. hastalığı var.
□ Hayır

2- Düzenli olarak kullandığınız ilaç var mı?

□ Evet (Lütfen ilaç ismini, kullanım süresini belirtiniz)
□ Hayır

3- Sağ ve sol bacağınızda ve belinizde herhangi bir ortopedik travma (çıkık) veya cerrahi müdahale geçirdiniz mi?

□ Evet
□ Hayır

4- Lütfen antrenman programınızı yazınız.

Antrenman: Haftada………gün………saat.
Kondisyon: Haftada………gün………saat.

5- Kaç yıldır futbol oynuyorsunuz? ……. Yıl.

6- Futbol dışında uğraştığınız bir fiziksel aktivite var mı? Var ise;

…………………..ile haftada………..gün……….saat.

APPENDIX D

YO-YO INTERMITTENT RECOVERY TEST LEVEL 2 ASSESSMENT SHEET

YO-YO INTERMITTENT RECOVERY TEST LEVEL 2 ASSESSMENT SHEET

No	Name & Surname	Polar	Shuttle 2X20)	Distance	Score
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					