EFFECTS OF MUSCLE FATIGUE ON SHOOTING ACCURACY IN HANDBALL PLAYERS

A THESIS SUBMITTED TO
THE GRDUATE SHOOL OF SOCIAL SCIENCE
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY
BEYZA ŞİMŞEK

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF PHYSICAL EDUCATION AND SPORT

SEPTEMBER 2012

Approval of the Graduate Schools of Social Sciences

Prof. Dr. Meliha Altunışık
Director

I certify that this thesis satisfy all requirements as a thesis for the degree of Doctor of Philosophy.

Prof. Dr. M. Settar Koçak
Head of Department

This is certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as thesis for the degree of Doctor of Philosophy.

Prof. Dr. Feza Korkusuz
Supervisor

Examining Committee Members

Prof. Dr. Feza Korkusuz	(METU, PES)	____________
Prof. Dr. M. Settar Koçak	(METU, PES)	____________
Assoc. Prof. Dr. Emine Çağlar	(Kırıkkale U, PES)	____________
Assist. Prof. Dr. Murat Bilge	(Kırıkkale U, PES)	____________
Assist. Prof. Dr. Sadettin Kirazcı	(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: Beyza Şimşek

Signature:

ABSTRACT

EFFECTS OF MUSCLE FATIGUE ON SHOOTING ACCURACY
IN HANDBALL PLAYERS

Şimşek, Beyza
PhD. Department of Physical Education and Sport
Supervisor: Prof. Dr. Feza Korkusuz

September 2012, 75 pages

The purpose of the study was to investigate the effects of muscle fatigue on shooting accuracy in male handball players. Sixteen elite young male handball players (age: 17.12±1.74 year; height: 185.26±7.17; body mass: 78.93±11.07) volunteered to participate in the study. The study composed of laboratory and field test sessions. In the laboratory test, maximal oxygen consumption (VO2max) obtained from treadmill running test, blood lactate concentration, heart rate monitoring at resting and every 3 minutes during running were measured. Running speed equal to 75% speed at VO2max values of participants was used as initial velocity for 30-15 intermittent fitness test (30-15IFT). In the field tests, after determined the optimum shooting velocity of each participant, they shots to each targets placed at the four corner of the handball goal 4 times, totally 16 times. Blood lactate concentration was measured from the earlobe of participant who completed shooting to target test session. Then, 30-15IFT was applied as fatigue protocol and at the end of the test, blood lactate concentration was measured again and participant repeated shooting to target test session immediately after fatigue protocol. During all shooting procedures, acceleration of wrist and speed of ball were recorded. Blood lactate concentration over 8mmol/L, 90% of HRmax, respiratory exchange ratio>1 and exhaustion of participant accepted ending criteria for the tests. As a result, no significant differences were found between pre-fatigue and post-fatigue protocols in terms of accurate and inaccurate shots. Shooting consistency, ball speed, response time, X, Y, Z axis of wrist acceleration variables highly correlated each other in terms of shooting accuracy both in pre and post fatigue conditions. Shooting consistency has an effect on accurate shots. Ball velocity has effect on inaccurate shots in pre-fatigue condition. However, none of variable has effect on accurate and inaccurate shots in post-fatigue conditions. In pre-fatigue conditions, right to left motion of wrist (X axis) was the most important motion, back to forward motion (y axis) was became more important in post fatigue condition.

Key Words: Team handball, Shooting accuracy, Fatigue protocol, 30-15IFT, Accelereation

ÖZ

ERKEK HENTBOL OYUNCULARINDA KASSAL YORGUNLUĞUN ATIŞ İSABETİNE ETKİSİ

Şimşek, Beyza
Doktora, Beden Eğitimi ve Spor Bölümü
Danışman: Prof. Dr. Feza Korkusuz

Eylül 2012, 75 sayfa

Araştırmanın amacı erkek hentbol oyuncularında kassal yorgunluğun atış isabetine etkisinin araştırılmasıdır. 16 elit genç erkek hentbol oyuncusu (yaş: 17.12±1.74 yıl; boy uzunluğu: 185.26±7.17cm; vücut ağırlığı: 78.93±11.07kg) çalışmaya gönüllü olarak katılmışlardır. Çalışma laboratuvar ve saha testlerinden oluşmuştur. Laboratuvar testlerinde her 3 dakikada kan laktat konsantrasyonu ve kalp atım hızı ölçülmüştür. Bireysel yorgunluk protokolünün (30-15 intermittent fitness test) şiddetini belirlemek için gerekli VO2max değeri (VO2max değerinin %75'i) koşu bandı testinden elde edilmiştir. Saha testlerinde ise, öncelikle optimal şut hızı belirlendikten sonar katılımcılar her hedefe 4'er adet olmak üzere toplamda 16 adet şut atmışlardır. Sonrasında katılımcının 30-15IFT öncesi ve sonrasında laktat konsantrasyonu ölçülmüştür. Yorgunluk protokolünün hemen akabinde katılımcılar tekrar hedefe şut atmışlardır. Tüm şut performansları esnasında bileğin ivmelenmesi ve topun hızı ölçülmüştür. Kan laktat konsantrasyonunun 8mmol/L değerinin, RER değerinin 1'in ve kalp atım hızının maksimumun %90'ının üzerine çıkması testi sonlandırma kriteri olarak Kabul edilmiştir. Sonuç olarak, yorgunluğun atış isabetini değiştirmediği bulunmuştur. Yorgunluk öncesi ve sonrası atış isabet değerleri açısından atış tutarlılığı, top hızı, tepki zamanı, bileğin X, Y, Z eksenlerindeki ivmelenmesi değerleri arasında yüksek düzeyde anlamlı ilişki, tespit edilmiştir. Atış tutarlılığının isabetli atışlarda etkisi olduğu bulunmuştur. Top hızı isabetsiz atışlarda

yorgunluk öncesinde etkili olmuştur. Fakat, yorgunluk sonrasındaki isabetli ve isabetsiz atışlarda hiç bir değişken etkili olamamıştır. Yorgunluk öncesi durumda bileğin sağdan sola hareketien önemli etken olmuş iken yorgunluk sonrası bileğin arkadan öne doğru olan hareketi daha çok önem taşır hale gelmiştir.

Anahtar kelimeler: Hentbol, Atış isabeti, Yorgunluk protokolü, 30-15IFT, İvme.

To My Children Eylül and Kartal

ACKNOWLEDGEMENTS

I would like to express my gratitude to my advisor Prof. Dr. Feza Korkusuz for his guidance throughout this study.

I would like to thank to the committee members, Prof. Dr. Emin Ergen, Prof. Dr. Settar Koçak, Assoc. Prof. Dr. Emine Çağlar, Assist. Prof. Dr. Sadettin Kirazcı and Assist. Prof. Dr. Murat Bilge for their suggestions and comments and ideas for developing this study. I am grateful to Assist. Prof. Dr. Murat Bilge also for his support during measurements.

I would also like to thank to Dr. Pınar Arpınar Avşar for her support during all the measurement and Assist. Prof. Dr. Gökhan Deliceoğlu for his support during all the measurement and statistical analysis.

I would like to thank to Assoc. Prof. Dr. Ertuğrul Gelen, Assist. Prof. Dr. Tahir Hazır, Dr. Sinem Mavili Hazır for provide me measurement devices.

I would like to acknowledge the support and patience of all of the participants.

Finally, I am greatly indepted to my parents and my husband Vefa Şimşek for their constant encouragement.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVATIONS

30-15IFT	30-15 Intermittent Fitness Test
Acc	Accurate
BMI	Body mass index
HR	Heart Rate
HRmax	Maximum heart rate
Inacc	Inaccurate
Km.$^{-1}$	Kilometer per hour
La	Blood lactate concentration
mSD	Mean of standard deviations
Pre-acc	Accurate shot at pre-fatigue condition
Pre-inacc	Inaccurate shot at pre-fatigue condition
Post-acc	Accurate shot at post-fatigue condition
Post-inacc	Inaccurate shot at post-fatigue condition
RER	Respiratory exchange ratio
SCon	Shooting consistency
VIFT	Speed at 30-15 Intermittent fitness test
VO2max	Maximal oxygen consumption
v VO2max	Speed at maximal oxygen consumption

CHAPTER I

INTRODUCTION

Competitive team handball is an intermittent high intensity body-contact team sport that requires a combination of aerobic and anaerobic fitness to perform a sequence of well-coordinated activities (Chelly, 2011; Buchheit et.al., 2009; Buchheit and Leprette, 2009; Delamarche, 1987; Rannau, 2001). Team handball places a heavy emphasis on sprinting, running, jumping and throwing (Gorostiaga, 2006). Motor ability, sprinting, jumping, flexibility and throwing velocity represent physical activities that are considered as important aspects of the game and contribute to the high performance of the team (Zapartidis et al., 2009).

Passing and catching are the most important components of ball control in team handball. Offensive success revolves around a team's ability to move the ball quickly and accurately from one player to another. Consistent, accurate passing ensures the paces and continuity of team play and keeps pressure on the defense by allowing each attacker the opportunity to be a scoring threat (Clanton & Dwight, 1997).

All activities in team handball are performed in specific conditions, with the presence of players of the opposing team and while observing playing regulations. Their selection and execution therefore depend mostly on the situations in the match (Pori et al., 2005).

Michalsic et al.a, (2011), defined the movement categories and sum of distance of these categories as standing still (0 km.h^{-1}), walking (4 km.h^{-1}), jogging (8 km.h^{-1}), running (13 km.h^{-1}), fast running (17 km.h^{-1}), sprinting (24 km.h^{-1}), sideways movement (10 km.h^{-1}) and backwards running (10 km.h^{-1}) in their studies.

There are four basic shots in team handball. The set shot is the most natural of all shooting actions and is simply the overhand pass thrown hard. The “jump shot” is the most used shot in team handball. Developing the ability to jump and shoot over the defence, as well s jumping inside the goal area, will make athletes more effective scoring threat. The “wing shot” is the jump shot performed at a difficult shooting angle. The “fall shot” is the basic technique of the circle runner. It allows receiving the ball on the 6 meter line and shooting without using three steps (Clanton & Dwight, 1997).

For the set shot to be effective it must be performed quickly. In preparation phase of movement, player runs to receive to get into shooting position. The momentum created from being in motion will increase the power of player’s shot. Players attacks using three steps and during the second step, ball is brought up to head height. Elbow is flexed to 90 degrees or greater. At that time, all of body weight should be on back foot, upper body should be upright and shoulders perpendicular to the goal. Player should keep head up and eyes on goalie. In execution phase of movement, to shoot step forward and transfer body weight from rear foot to front foot. Shoulders are rotated and opened for being parallel to the goal. Player begins moving arm forward by leading with elbow, then whip forearm and snap the wrist. In follow-through phase of movement, momentum of body continues forward and the motion of throwing arm continues across body (Clanton & Dwight, 1997).

The referee awards a 7-meter throw when a fault obstructs a clear scoring opportunity. Generally, the set shot and the fall shot are used for 7-meter shot. The 7-meter throw is an important part of the game to go scoring (THF, 2010).

In the study of Skarbalius (2010), they analyzed Olympic and European Handball matches and emphasized that, throughout Handball Championship

2002-2010 teams on average earned a 7 m penalty 4.3-4.8 times per match, performed steals 3.1-5.1 times and made 11.2-12.5 mistakes. In addition to this data, 7m shots efficacy for winner are 66.9% in 2002 and 69.7% in 2010; 7m shots efficacy for winner are 65.2% in 2002 and 72.5% in 2010.

Clanton & Dwight (1997) also stated that shooting the ball hard is not enough to beat a goalie; accuracy is essential. A direct shot is quicker and more accurate. According to them velocity is as important as accuracy. Player can be accurate but if velocity is not enough, goalie will have more time to react and block to shots.

According to Marczinca (1993), the greatest speed can be achieved if the power is concentrated on the center of gravity of the ball, to go through the balls axis of rotation so that its driving moment is 0. In this case, the ball progresses without spinning and this reduces the drag so that the speed of the ball increases. The speed of the ball initially depends on the exertion of the player and its size is determined by players' purpose such as carry out a pass or goal shot.

Velocity of handball throw is an important aspect for success, because the faster the ball is thrown at the goal, the less time defenders and goalkeeper have to save the shot.

Michalsic et al. (2011) studied on differences in the general and specific capacities of throwing in function of age. The participants were assessed in four different situations of progressive specificity: throw with a heavy medicine ball, throw with a light medicine ball, throwing velocity without opposition i.e. with no with a goalkeeper at the goal. As a result they found that senior players were found to perform far better than the U-18 players in all four throwing situations and throwing velocity was higher without than with opposition for both groups; (senior group lowered by 7.79% and U-18 group lowered 6.03%). Accoring to results they suggested that age can be a determining factor in handball players' throwing capacity and the presence and interference of a goalkeeper appears to affect throwing velocity in a negative way

.

1.1. The purpose of the Study

The purpose of the study was to investigate the effects of muscle fatigue on shooting accuracy in male handball players.

1.2. Research Questions

Research study of this study were,

- Whether fatigue will affect shooting accuracy?
- Whether fatigue will affect wrist acceleration?
- Whether fatigue will affect ball speed?
- Do the ball speed, wrist acceleration and shooting accuracy correlate each other?

1.3. Operational Definition

Acceleration: time rate of change of velocity which is a vector quantity. Acceleration is expressed in ms^{-2}.

Acceleration Level: the ratio of measured acceleration level to reference acceleration level.

Accelerometer: a transducer which produces an output (usually electrical), which is proportional to the acceleration in some specific axis, along a specified direction.

Acceleration amplitude: the maximal value of a sinusoidal acceleration.

Axis: one of the three mutually orthogonal straight lines passing through the origin of a Cartesian co-ordinate system (i.e., translational axis, X axis, Y axis and Z axis)

Body Mass Index (BMI): A controversial statistical measurement which compares a person's weight and height.

Consistency: Mean of standard deviations (mSD) of total acceleration vectors per target

Maximal oxygen consumption (VO2max): The maximum amount of oxygen that can be consumed per minute during maximal exercise; also known as aerobic power and maximal oxygen consumption rate.4

Maximum Heart Rate (HRmax): The highest number of times a human heart can contract in one minute.

1.4. Assumptions of the Study

The following assumptions have been determined in this study:

1) It is assumed that participants understood and followed instructions related with tests.
2) It is also assumed that participants gave their best efforts during performance tests.

1.5. Limitations of the Study

The study was restricted by the following limitations:

- Study was limited by sample size (n=16)
- Participants of this study were limited to young male handball players.
- Number of shooting to each target limited to four shots in order to avoiding elimination of fatigue effects during shooting.

1.6. Significance of the Study

Accuracy is one of the most important terms in order to reach optimum result in team handball because of being high intensity intermittent types of sport. Endurance also important factor in order to coping with fatigue for athletes. During a handball match which composed of 2 periods, totally 60 minutes, handball players not only have well developed aerobic and anaerobic capacity but also should perform high intensity movements such as sprinting, jumping or throwing. These requirements of high intensity movements also can cause fatigue. As it takes place literature also, fatigue is a factor that affects performance negatively. This study aimed to give answer to the research question whether muscular fatigue affects shooting accuracy and wrist acceleration. From that point in preparing training programs it can be useful knowledge for athletes and coaches. In addition, there are some laboratory or field studies about team handball related with physiological parameters, shooting velocity or fatigue protocol separately. In this study both laboratory and field tests applied and physiological parameters, shooting accuracy and shooting velocity under resting and fatigue conditions combined in same study. Especially field study design which was set for current study, can be also used for developing shooting effectiveness in regular trainings in terms of being applicable for players and coaches.

CHAPTER II

LITERATURE REVIEW

2.1. Physical and physiological demands of Handball

Team handball is a complex intermittent sport game which requires players to have well developed aerobic and anaerobic capacities (Delemarce,1987; Grostiaga, 2006). Several motor abilities such as sprinting, jumping, flexibility and throwing velocity are considered as important aspects of the game that contribute to the high performance of the team (Granados, 2007; Marques, 2006). Zapartidis (2009) pointed that the importance of VO2max in terms of distinguishing young players according to their level. Depending on the level of competition and the position in the team, players usually cover a distance between 4.5-6.5km and require high level of aerobic capacity to aid recovery after high-intensity bouts of activity. On the other hand, he stated that a number of differences in anthropometric and physical fitness characteristics exist between playing position.

2.2. Maximal oxygen consumption

The single most reliable (r_{xx}>.80) and valid measure of aerobic capacity is the maximal oxygen consumption, or VO_2max (ACSM, 2000, Morrow, JR. et al., 2005). VO_2max is a measure of the maximal amount of oxygen that can be used by a person during exhaustive exercise. VO_2max is achieved when the work rate is increased, but the oxygen consumption does not increased or has reached a plateau. Other indicator of VO_2max are a respiratory exchange ratio (RER) greater than 1.1 and heart rates near age-predicted maximal levels, lactate concentration over 8mmol/L, and exhaustion of participant (Shephard,1992,Morrow, JR. et al., 2005).

Zapartidis (2009) pointed that the importance of VO2max in terms of distinguishing young players according to their level. Depending on the level of competition and the position in the team, players usually cover a distance between 4.5-6.5km and require high level of aerobic capacity to aid recovery after high-intensity bouts of activity.

In literature, VO_2 max was defined as an important factor that being a clue of aerobic capasity. There were some values about VO_2max of atletes that differ from sports. For example, an elite marathoner exhibits a high VO_2max (more than 80ml/kg/min), middle or long distance runner, road cyclists, swimmers (70-80 ml/kg/min), team game players (60-70 ml/kg/min), whereas the sprinters exhibits a comperatively lower VO_2max (45-55 ml/kg/min). VO_2max is restricted to only the individuals' cardiorespiratory capasity relating the O2 uptake, transport and utilization. It has been observed that individuals with similar VO_2max have variability in endurance capasity and that highly trained athletes perform at a high percentage of their Vo2max with minimum lactate accumulation (Ghosh, 2004).

2.3. Blood lactate concentration

Anaerobic glycoliysis system relases energy for ATP synthesis through the partial breakdown of carbohydrates to lactic asid. Lactic asid causes muscular fatigue when it accumulastes in the blood and muscles. When energy requirements increase during progressive exercise intensity, more pyruvate will be produced through increased anaerobic glycolysis (Fox, 1988).

A wide variety of factors influence blood lactate and heart rate response to exercise including: training status, carbohydrate intake, hormonal factors, hydration status, and environmentsal factors (Hellemans, 1993).

Blood lactate concentration can be measured during exercise. The most common sampling sites are the forearm vein, the earlobe capillary and the finger capillary (Hellemans, 1993). There is a point at which the blood lactate concentration sharply raises and this point has been termed the onset of blood lactate accumulation (OBLA). At very low exercise intensities, the concentration of the blood lactate is nearly identical to levels recorded at rest. At particular level of exercise intensity blood lactate concentration begins to increase. Anaerobic metabolism is used to supply the energy required to continue work. Lactic asid is a by-prrodukt of this anaerobic metabolism.Once formed, lactic asid will be almost completely dissociated in the serum and it is buffered predominantly by the bicarbonate system (Washington, 1999).

Royal et al. studied on water polo players and their study aimed to assess the effects of fatigue on decision making and goal shooting skill. It was reported that incremental increases in fatigue improved decision making, decreased the technical performance and accuracy and ball speed was unchanged.

Intermittent exercise allows players to work for longer durations than continuous exercise at the same intensity through reduced lactate accumulation because lactate is partly metabolized during recovery periods.

2.4. Heart Rate

Heart rate increases during physical activity are controlled by the sinoatrial node in response to decreased parasympathetic neurol stimulation and increasedsympathetic neurol stimultion-a phenomenon termed cardiac chronotropic regulation (Robergs, 1996; Janz, 2002). Throughout a large range of physical activity, moderate through vigorous, heart rate increases linearly and proportionately with the intensity of movement and the volume of oxygen consumed (VO_2) by contracting skeletal muscles (Freedson & Miller, 2000).

Temperature, humidity and altitude, emotional stress, digestion, nicotine, altitude all result in an increase in metabolic stress and an accelerated heart rate response (Hellemans, 1993; Freedson, 2000). Physical fitness is also a factor that cause differences between physically fit and unfit person in terms of heart rate because stroke volume is higher for the fit individual (Nieman, 1999; Rowlands,1997).

There are variety of factors that influence the HR-VO_2 relationship during physical activity such as specific muscle mass utilization, type of activity, Physical fitness level and other exercise related factors. Both lower body dynamic activity (e.g., running) and upper body dynamic activity (e.g., rowing) result in nearly linear associations between heart rate and $VO_{2.}$ However at any given submaximal VO_2 heart rate is approximately 10% higher for upper body exercise compared to lower body exercise because of reductions in stroke volume and arterial-venous oxygen difference during upper body movement. This means that one subject running and another rowing at the same activity level (the same submaximal VO_2) would have different heart rates (Janz, 2002). In addition, at the same submaximal VO_2 heart rates are higher during static exercise than during dynamic exercise. This is because during static exercise heart rate is proportional to the active muscle mass and the percentage of maximal voluntary contraction rather than oxygen consumption (Nieman, 1999).

During static exercise, increased vascular resistance reduces stroke volume, so elevated heart rates also reflect the body’s efforts to maintain cardiac output (Hurley et al., 1984).

Heart rate data are used to predict energy expenditure by establishing subject-specific regression equations between heart rate and volume of oxygen consumed. This method requires establishing a heart rate curve using laboratory measures for each individual study subject (Ceesay et al., 1989). On of the approaches for estimating energy expenditure from heart rate are flex heart rte method which is defined as the mean of the highest heart rate at rest and the lowest during exercise. It commanly determined by measuring heart rate at rest and during progressive increases in exercise and then calculating the mean of the highest resting valu and lowest exercise value (Wareham et al., 1997). Percent heart rate reserve are based on the assumption of a linear and equivalent relationship between %heart rate and %VO_2 reserve throughout a large range of dynamic activity (Swain, 1997). In average net heart rate method, monitored heart rate substracted from the resting heart rate. A fourth method is heart rate threshold for constructing outcome variables is to determine the number of minutes or % of a time period greate than or equal to a selected target heart rate without adjusting for resting heart rate (Armstrong, 1998).

Handball is highly intensive game and during whole match, handball players' mean heart rate was reported between 75-80% of maximum heart rate by Chirosa et al. (1999).

2.5. Muscular fatigue and performance of a motor skill

Green (1995) stated that, repeated attempts to reproduce equivalent mechanical expressions are invariably met with failure, as characterized by an early and progressive deterioration in performance. This deterioration is recognized as fatigue.

According to Hause et.al (2003) neuromuscular fatigue can be defined as transient decrease in muscular performance usually seen as failure to maintain develop a certain expected force or power output.

Fatigue also has been classified as being either central and peripheral origin. Central fatigue is described a reduction in neural drive or motor command to the muscle resulting in a decline in force or tension development. On the other hand peripheral fatigue is defined as decrease in force generating capacity of the skeletal muscle due to action potentiasl failure, excitation contraction coupling failure or impairement of cross-bridge cycling in the presence of unchanged or increased neural drive (Kay, 2000).

The cause of muscle fatigue varies and depends upon type of exercise performed. Fatigue resulting high intensity exercise appears to be due to an accumulation of inorganic phosphate and hydrogen ions within the muscle fiber. These metabolites interacts with the contractile proteins and reduces muscle force production. In prolonged exercisemay involve the failure of excitation - contraction coupling. This is likely due to reduction in the relase of calcium from the sarcoplasmic reticulum. Reduced calcium relase results in fewer myosin cross-bridges in the strong binding state and reduced force production (Uzun, 2002).

The recruitment of muscle depends, in part, conscious control. The physiological trauma of exhaustive exercise may inhibit the athlete's willingness to tolerate further pain. Perceived discomfort of fatigue precedes the onset of a physiological limitation within the muscles (Enoka, 1995).

According to findings of many studies, central nervous system is primary site of fatigue but did not rule out peripheral sites such as the neuromuscular junction and the muscle fiber itself. Fatigue has not only effects strength and reflexes, but also effects coordination of complex movement (Hause et.al, 2003).

Many researchers studied on manifestations and effects on fatigue mechanism. Kluka (1999) claimed that the physiological fatigue affects an individual's motor learning and performance multidimensionally. One of the affected dimensions is that of concentration. The higher level of fatigue, more detrimental the performance outcome. Low to moderate levels of fatigue seem to have no effect on learning but lead to decreases in performance. High levels of fatigue may affect both.

Green (1995) asserted that there are some important variables constituting the task itself, such as the muscle mass involved, the intensity of the contraction, the velocity of movement, the range of muscle lengths at which the task is performed there are large and the temporal characteristics of the contraction and relaxation schedule and there appear to be large differences between individuals in the vulnerability to fatigue such as sex, age, health status, body composition and genetic endowment in terms of the structure, organization and composition of the neural and the muscular system.

Physical fatigue reduces neuromuscular and sensorimotor control ant that the occurrence of these impairments may contribute to an increased lower limb injury risk (Zech, 2012).

2.6. Term of accuracy

Schmidt & Wrisberg (2004) were expressed accuracy as the amount of variability or inconsistency of performer’s movement end point in the target area.

Accuracy can be divided into three such as spatial accuracy, temporal accuracy and timing accuracy. Spatial accuracy required of aiming movements for which spatial position of the movement’s end point is important to task performance. Speed or distance is decreased such as down the line serve in volleyball; dart throwing; target archery. Temporal accuracy required of rapid movements for which accuracy of the movement time is important to task performance; more commonly referred as timing accuracy. The last one is timing accuracy required of rapid movements and decreased movement time for also referred to as temporal accuracy such as tennis drive or badminton smash (Schmidt & Wrisberg, 2004; Kluka, 1999).

.

2.6.1. Fitts Law

Fitts' law suggests that there is a trade of between speed and accuracy. When speed is emphasized, accuracy is reduced; when accuracy is emphasized, speed is reduced. If the goal of the movement involves primarily spatial accuracy such as throwing darts at a target, movement should be made more slowly to reduce spatial errors. If the movement goal primarily involves temporal accuracy such as when to swing the bat at the ball in cricket, increasing the speed of the movement will reduce errors in timing accuracy (Kluka, 1999).

For discrete, rapid aiming movements, spatial accuracy decreases with increases in movement speed, up to about 70% percent of maximum speed (Wrisberg, 2000).

In movements rapidly produced (lasting 200ms or less) where little or no feedback processing is possible, it was seen that increases in movement distance (from 10 to 20 to 30cm)are accompanied by gradual increase in the spread of variability of the movement end points. Also it was seen that a decrease in movement time from 200ms to 140ms increases the spread as well. This means that aiming errors are influenced both by increases in movement distance and by decreases in movement time. In addition, decreases in movement time also affect the consistency of the processes that generate the initial parts of the action. That is they affect the open-loop processes necessary to produce a quick movement (Schmidt & Wrisberg, 2004).

2.6.2. The Importance of accuracy in handball

Shooting the ball hard is not enough to beat a good goalie; accuracy is essential. Shooting for the corners is one of the important principles of shooting. The high corner cobwebs are under the crossbar and inside the goalpost. The low cobwebs are where the goalpost meet the floor, above where the goalie’s foot can extend and below where the goalie’s hand can reach.

Wagner & Müller, (2008) stated that, in elite team handball, shooting on goal is one of the most important aspects of the game. For a shot to be successful, it requires maximum ball velocity and precision as well as an element of surprise for the defensive players and goalkeeper. They also claimed that the internal shoulder rotation angular velocity at ball release, maximal elbow extension and the timing of the maximal pelvis angle are important contributors to the ball velocity.

2.7. Throwing movement in handball

Marczinca (1993), defined the purpose of throwing motion is to smoothly transfer the kinectic energy gained by building up impetus to the ball and throw it with the appropriate muscle power. In the throwing position, with the help of the pre-stretch muscles, he transforms the kinetic energy to potential energy so that during the throwing motion, he can use it as kinetic energy again to give the ball more power impulse.

In team handball competition, 73-75 % of all throws during the game constitutes jump throws followed by the standing throw with run-up (14-18%), penalty throw (6-9%), diving throw 2-4%) and direct free throw (0-1%). These techniques are used to increase the horizontal velocity making it difficult for the defensive player to tackle and potentially enabling a higher ball velocity (Wagner, 2008;2011).

Fradet et al. (2004) studied on French handball players and they claimed that maximal linear speed of the shoulder occurred after maximal linear speed of the elbow. On the other hand, according to Wagner (2008), the main reason why top players produced higher ball velocities than less proficient players was the velocity of the shoulder, especially shoulder flexion, together with elbow extension and ulnar deviation at the wrist. In another study which belongs to Wagner et.al (2011) it was reported that there were high and significant correlations to the ball velocity for the maximal pelvis and trunk rotation.

According to Van den Tillaar and Ettema (2004), 67% of ball velocity at ball release can be explained by the summation effects from the velocity of elbow extension and internal rotation at the shoulder. Van den Tillaar and Ettema (2007) showed a significant correlation for the timing of the maximal pelvic angle with ball velocity, indicating that the best throwers started to locate their pelvis forward earlier during the throw. In addition to this, Zapartidis (2007) pointed that improvement of the strength of the rotators of shoulder could aid players to achieve and maintain a faster ball velocity and higher throwing effectiveness during the game.

Zapartidis (2007) stated that for a throw to be effective, the highest velocity at ball release in combination with aiming accuracy are both required and the athlete should maintain the potential of the optimal output in both of these parameters during the game.

Herbert (2008) asserted that handball throw is whole body, acyclic, complex and highly dynamic movement and it is important to optimize the movement of the throwing arm, in particular the velocity of the shoulder, elbow and wrist. The impulse transfers from proximal to distal segment such as hip, shoulder, elbow, wrist, middle hand and finger so that the ball finally reaches maximal speed.

2.8. Intermittent Exercises

30-15$_{IFT}$ is an attractive alternative to classic continuous incremental field tests for defining a reference velocity for interval training prescription in team sport athletes (Buchheit 2009).

For any continuous test (including no recovery period) differentiating the final velocity reached from what is called the maximal aerobic velocity. Actually during an intermittent test, maximal oxygen uptake is often reached before the end of the test. After the attainment of VO_2max the player has used some anaerobic sources to finish the last stage. While vVO_2max is a true and valid index of maximal aerobic function, the end- test velocity can be considered as a composite velocity (Buccheit, 2010).

In team handball, players do not carry out in-line or continuously running action. Chelly et al, (2011) divided locomotor activities into 5 categories during handball game which was represented in Table 1.

Table 1. Categories of locomotor activity during a handball game (Chelly,2011).

Category	Speed ($m.s^{-1}$)	Speed ($km.h^{-1}$)
Standing	0-0.1	0-0.36
Walking	0.2-1	0.37-3.6
Jogging	1.1-3	3.7-10.8
High-intensity running	5.1-7	18.1-25
Sprinting	>7.1	>25.1

At this point, team handball is a complex intermittent sport game which requires players to have well developed aerobic and anaerobic capacities

(Zapartidis, 2009; Delamarce, 1987). Besides, Chelly et al. (2011) were examined the activity profile of elite adolescent players during 6 regular handball matches and compared physical and motor performance of players between first and second half of the game. As a results of the study, they were represented the percentage of total running distance covered; 59% jogging, 29% walking, 8% high intensity running and 4% sprint. It was also represented the running distance 170±24 m at high intensity and 86±12m at maximal speed, at speeds>18km.$^{-1}$. In the study of Michalsik (2011), the mean score of total effective playing time was determined as 53.85±5.87 min, standing still and walking constituted 76.5±10.4 % of total effective playing time. In contrast, amount of high intensity running constituted 1.7±0.9% of the total effective playing time corresponding to 7.9±4.9% of total distance covered per match. In addition, 53.3±14.2 times high intensity runs were performed by all players.

CHAPTER III

METHODOLOGY OF THE STUDY

3.1. Participants

Sixteen elite young male handball players volunteered to participate in the study. Descriptive statistics about subjects are given in Table 2. All subjects and their family were provided with the procedures, potential risks and discomfort associated with participation in current study and sign written informed consent and parents' consent form prior to participation. The procedures were approved by the Ethics Committee of the Middle East Technical University.

Table 2. Descriptive Statistics of the Participant Age, Training Age, Height, Weight and Body Fat Percentage.

Variable	Mean	Std.Dev
Age (year)	17.12	1.74
Training age (year)	9	1.41
Height (cm)	185.26	7.17
Body mass (kg)	78.93	11.07
Percent of body fat (%)	9.73	3.20
BMI (kg/m^2)	22.92	2.26

3.2 Data Collection and Instrumentation

The current study composed of 2 sessions such as laboratory and field test sessions. Each subjects visited the laboratory or sports hall 1 times on at approximately the same time of the day. Measurements applied morning sessions and first day 5 subjects, second day 5 subjects and third day 6 subjects participated to tests separated 30 minutes periods each other's. There were 48 hours between laboratory and field test for each subjects. Subjects who completed laboratory tests, passed through the field tests at the same order. All laboratory and field measurements were completed within 6 days.

According to study design, first of all subjects participated to laboratory tests including blood lactate concentration measurement, heart rate monitoring and treadmill test. VO_2max values of participants obtained from treadmill tests in order to determine relative running speed (75% of VO_2max) for 30-15 intermittent fitness test. In the field tests, firstly optimum shooting velocities of participants were determined. In pre-fatigue shooting test, participants shots to each target 4 times (totally 16 times). After that, blood lactate concentration of participant was measured and participant was begun to perform $30\text{-}15_{IFT.}$ At the end of the $30\text{-}15_{IFT,}$ blood lactate concentration was measured again and participant was repeated shooting to target procedures as post-fatigue shooting test as soon as possible. During all shooting procedures, acceleration of wrist and speed of ball were recorded.

Blood lactate concentration over 8mmol/L, 90% of HRmax values which were calculated according to age, and exhaustion of participant accepted ending criteria for the tests (Shephard,1992).

3.2.1. Laboratory Tests

Height measurement of handball players was performed by a stadiometer (Holtain, England, sensitivity ± 1mm). Body mass and percentage of body fat measurement were performed by a body composition analyzer (Tanita TBF 300, Japan).

3.2.1.1. Heart Rate Monitoring

Heart rate (HR) monitoring System (Polar S 810İ Polar Electro OY, Finland) was fitted to each players before the treadmill test and 30-15_{IFT} test. During all testing sessions including laboratory and field tests, resting HR and maximum HR values of each participant were recorded. In addition, every 3 minutes during treadmill test and at the end of every 30 s running session during 30-15_{IFT} test HR values of participant recorded also by using heart rate monitoring system. 90% of maximal HR of subjects' was accepted as ending criteria for the test.

3.2.1.2. Determination of VO_2max and vVO_2max

In this study pulmonary oxygen uptake was measured by a breathby-breath gas analyzing system (JAEGER MasterScreen CPX; Viasys Healthcare GmbH, Hoechberg, Germany). and Jager LE 200 CE treadmill. The analyzer was calibrated before each test. All subjects performed an incremental test on treadmill in order to determine VO_2max and the running velocity associated with VO_2max (vVO_2max) for setting relative fatigue protocol which was executed in field tests. A 0.5 percent slope was used during the whole tests. Treadmill speed started was 8 $km.h^{-1}$ as a warm up session and continue with 9 $km.h^{-1}$ and increased $1km^{-1}h$. every 3 minute and each 3 minute stage was separated by a 30 second passive rest period (Demarie, 2000; Midgley, 2007) and during these passive rest periods, lactate concentration measurement were done. Breath by breath data were stationary time averaged over 5 s. The test was ended when subject exhausted or HR > 90% of HRmax or La level > 8mmol/L. The highest VO_2 obtained during the last 40 s of the graded exercise test was considered to be the maximal oxygen consumption (VO_2max) (Belli et al., 2006).

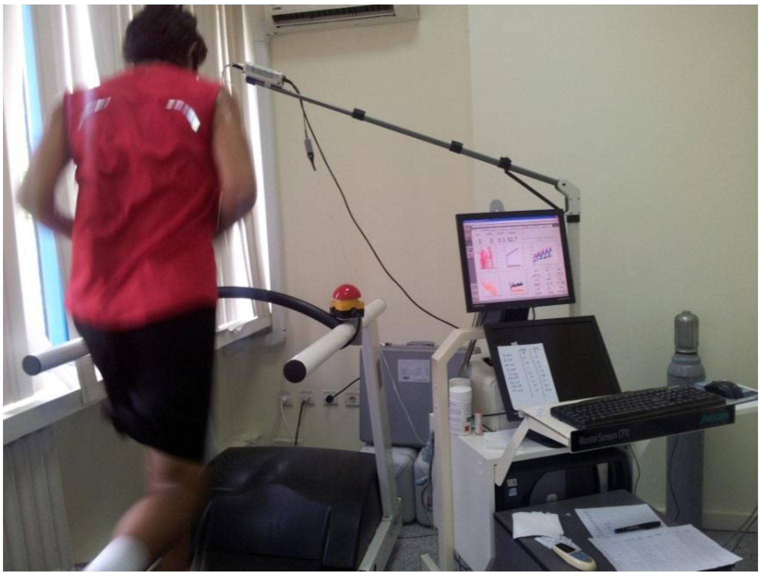

Figure 1. Treadmill test

3.2.1.3. Blood Lactate Concentration Measurement

25µl capillary blood sample were taken from an earlobe and analyzed samples immediately by using a lactate analyzer (YSI Sport 1500, Yellow Springs Instrument Co, USA). La was taken every 3 min in treadmill test. Analyzer was calibrated for every 5 subject. Before the tests and changes membrane and solution, 5.0 mmol/L and 30.0 mmol/L standard lactate solutions were used.

Figure 2. YSI 1500 Lactate analyzer

Figure 3. Lactate measurement

3.2.2. Field Tests

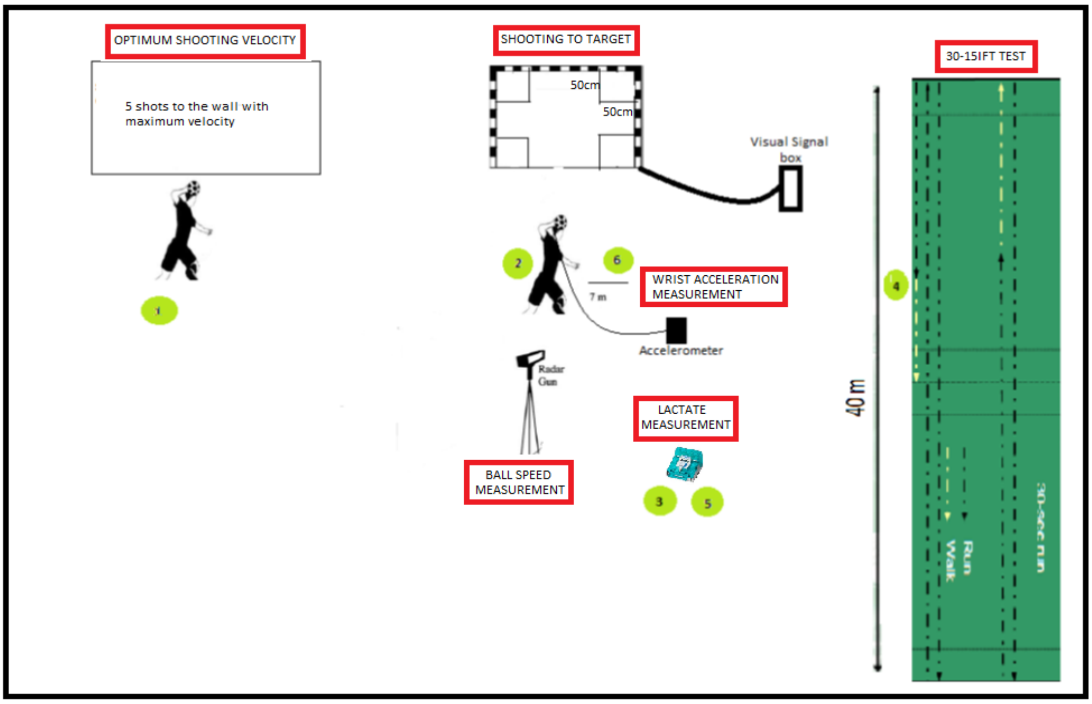

Figure 4. Field test design

3.2.1.1. Determination of Optimum Shooting Velocity

In order to assess the optimum shooting velocity, a standard handball was used (mass 475g; circumference 58 cm). Each subject executed 5 shots to the wall without target from the 7 m line. Shooting velocities were measured by using Sports Radar Gun SR 3600, USA. Radar gun was placed behind the participant and arrange the height according to the height of the participants’ throwing arm. Ball velocity is measured in km.h^{-1}. Except for minimum and maximum speed, mean value of the other 3 shots was calculated and 80% of this shooting speed was accepted as optimum shooting velocity.

3.2.1.2. Shooting to Target

Players throwed to the target from 7m line. A standard handball and goal specified by the International Handball Federation (IHF) guidelines were used (ball: diameter=58-60cm, weigth= 425-475gr, goal: width=3 m, height=2 m).

The four equal sized targets (50cmx50cm) hollow and made of iron was mounted at each corner of the goal (Figure 1). Each target is dressed by fish net like a cone in order to hold balls throwed to the target. These targets were chosen as the extreme points in the goal area and hence the targets most likely to give rise to differences in movement form (Bourne et al, 2011). Targets were labeled: top right (TR), bottom right (BR), top left (TL), and bottom left (BL) relative to the subjects viewing perspective.

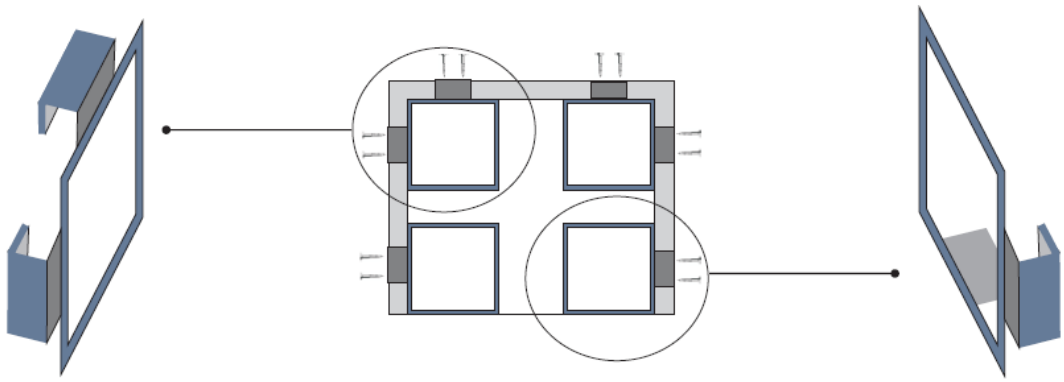

Figure 5. Target area setup on handball goal

Visual stimulus was used to designate the target. Four separate light panels assembled with 15 x 15 green LEDs with 3mm gap in between were attached to 1 m behind the goal where they were appeared by subjects as in the center of each target. Visual stimulus was given manually by control unit by pressing the designated button in order to turn on desired light according to the randomized order determined before the trials.

Before the trial with unfatigued condition, subjects were instructed to warm up as they would for a training session. After following 5 min resting period, subjects were asked to shoot the ball as fast as possible to the entire goal area without target to measure the speed of the ball as optimum ball speed reached by the subjects. Within 10 minutes after the completion of the maximal shooting experiment, the accelerometer was mounted on the subjects wrist and the shooting trials were initiated.

Figure 6. Shooting to target

A total of 16 shots were completed by each participant four times for each of four target locations. Participants were instructed that their feet had to remain in contact with the ground just behind the 7-m line and for using correct techniques and shooting with optimum velocity during the sixteen consecutive trials. Between each trial, there were 3 seconds for the subject to handle the ball given by a designated people standing one meter away from the subject and to be ready to react for the next visual stimulus in standardized shooting position. Accurate and inaccurate shots, shooting velocity of all shots and success of the target regions were recorded also.

3.2.1.3. Measurement of ball speed

Ball velocity was measured by a Sports Radar Gun (SR 3600, USA). The height of the radar gun was adjusted individually according to the player's throwing arm height. The velocity of ball recorded as $km.h^{-1}$.

Figure 7. Radar Gun

3.2.1.4. Response time measurement

Response time was operationally defined as the time difference between the onset of light trigger signal and the point where the peak acceleration was reached at x-axis. Thus, response times were calculated for each shooting action by using synchronized recordings of acceleration and light trigger signals (Figure 8).

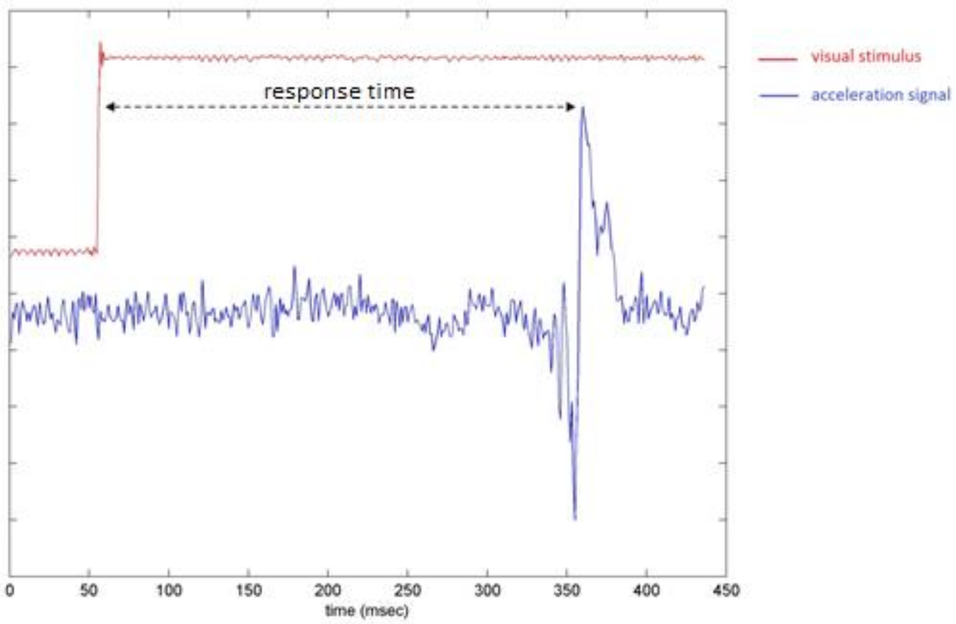

Figure 8. representation of response time according to visual stimulus and acceleration signal.

3.2.1.5. 30-15 Intermittent Fitness Test

$30\text{-}15_{IFT}$ consist of 30 second shuttle runs interspersed with 15 second passive recovery periods. Velocity was set equal to 75% of vVO2max values of subjects'. Initial velocity range from one subject to another depending on the differences on VO2max values of each subject for the first 30 second run and was increased by $0.5 km.h^{-1}$ every 45 second stage thereafter. The 30-15IFT was performed over a 40m shuttle distance, within which the subject had to run back and forth at a pace governed by a prerecorded beep, so that at each short beep sound the subjects should be within 3m zones at each extremity or in the middle of the course. During the 15s recovery period, athletes walked in the forward direction to join the closest line from where they started the next stage from a standing position. Exhaustion was defined as the inability to match the covered distance with the audio signal on three consecutive occasions, or until 90% of maximal heart rate of the subject. The last completed stage (VIFT) was used to predict VO2max using the equation below, proposed by (Buchheit et.al., 2009; 2010).

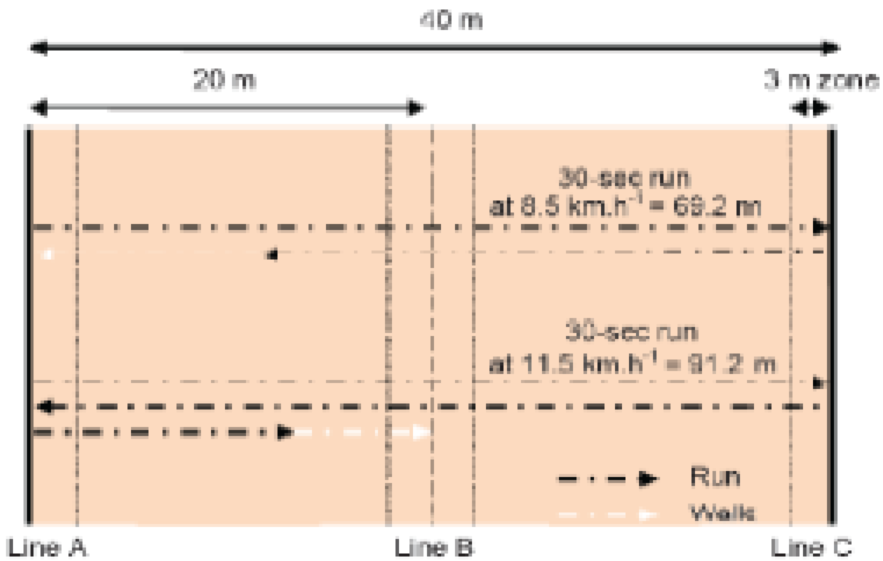

Figure 9. 30-15 Intermittent Fitness Test

3.2.1.6. Blood Lactate Concentration Measurement

La measurements repeated at the beginning and at the end of the $30\text{-}15_{IFT}$ test with same measurement method which was done at laboratory test.

3.2.1.7 Acceleration measurement

A tri-axial accelerometer (SS27L, ±50g range, Biopac, USA) was attached on the extensor retinaculum (dorsal carpal ligament) located on the back of the wrist, just proximal to the subjects' hands where x, y and z axis correspond, respectively to lateral (X, from right to left), horizontal (Y, from back to forward) and vertical (Z, from up to down) directions of the subjects' forearm (Figure 9). Double sided adhesive tape and elastic straps were used to fix the accelerometer to avoid undesired movement due to skin movement/vibration artifacts at best. The tri-axial (x, y, and z) recording of the acceleration data was started before the initiation of the sixteen consecutive trials. Acceleration signals were acquired using an analog-to-digital converter card (USB-1608FS, Measurement Computing, USA) at a sample rate of 1000 Hz per channel.

Figure 10.a) A tri-axial accelerometer mounted on wrist and

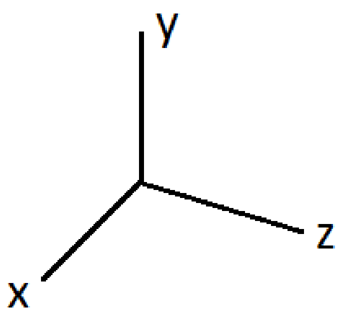

Figure 10. b) Three orthogonal directions (X, Y, Z)

Normalization procedures

The normalization procedure for each axis of acceleration data consisted of three stages. In the first stage, the mean value of the first 100 ms of acceleration signal recording at a resting condition was subtracted from the whole signal, such that during the initial resting condition of the wrist, the acceleration signal would be at zero, indicating no acceleration. Secondly, the whole signal was divided by a constant value according to the sensitivity characteristics of the accelerometer, to be able to represent the values in terms of Earth's gravity (g). Finally, normalization along the time axis was performed by shifting data such that the maximum instants get overlapped. The resultant 2 to 4 by 400 acceleration matrices (g vs. ms) corresponding 2 to 4 trials of each subject were used in further calculations.

Total Acceleration Vector

The acceleration pattern of the elbow during shooting a ball has three dimensional space, therefore the total acceleration vector (Acctotal) combined from three orthogonal directions (x,y,z-axes) was computed for each shot. The root mean square of each accelerometer axis signal is calculated in real time (equation 1) and vector sum of all three axes were used as total acceleration vector in order to use in comparisons between throwing patterns per target for successful or unsuccessful shots in pre fatigue and post fatigue conditions.

$$\mathrm{Acc}_{\mathrm{total}} = \sqrt{a_x^2 + a_y^2 + a_z^2} \qquad \text{(Equation 1)}$$

Calculation of consistency

Each of shots completed by each participant four times at each of four target locations was used for consistency calculation. Consistency defined as the mean of standard deviations (mSD) of total acceleration vectors per target (i.e. mean of standard deviations of 2 to 4 shots for each of four targets). The equation of mSD, the consistency score, is;

$$mSD = \frac{\sqrt{\sum_{i=1}^{m} \sum_{j=1}^{n} (E_{ij} - \overline{E}_i)^2}}{m.n.\max(E_{ij})}$$ (Equation 2)

Where m(=400) is the number of temporal points (400 msec before and after the peak), n is the number of acceleration epochs (accepted trial count between 2 and 4), Eij is the value of the jth in total acceleration signal at time epoch i, i E is the value of averaged acceleration waveforms at time epoch i.

mSD measures similarity of acceleration waveforms so that zero indicates exactly the same waveforms, corresponding to “no variability” or "maximum consistency" between the shots. If similarity decreases mSD increases (corresponding to higher variability or lower repeatability). The logic behind mSD is the same as standard deviation (i.e., mSD is a logical extension of “SD of one channel signal” to “SD of multichannel signal”) and amplitude normalization (it is further divided by number of signal points, m-times-n and maximum amplitude of m-by-n acceleration matrix signal, Eij) (Arpinar-Avsar, Soylu, 2010). The aim of the last amplitude normalization was to make the consistency measure (mSD) independent from the signal length, trial count, or the peak acceleration reached by the subject. Furthermore, similar to employing the maximum voluntary contraction for normalization procedures in surface electromyography, this amplitude normalization in acceleration signals also makes each repeatability measure comparable between subjects.

The sample representation of total acceleration vector obtained for successful and unsuccessful trials for pre fatigue conditions are illustrated in Figure 11 (a and b).

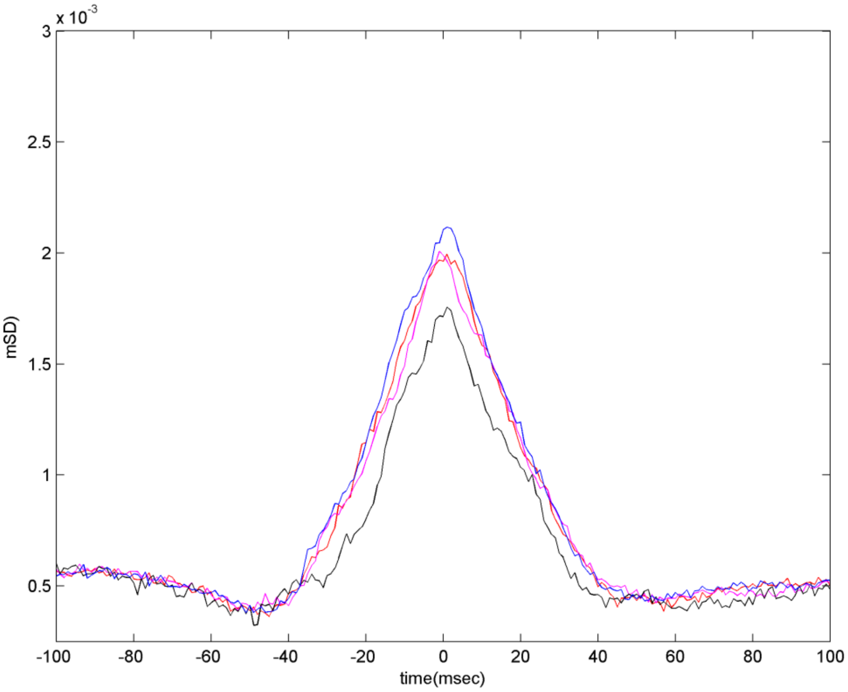

Figure 11.a) Successful shots per target (Acctotal)

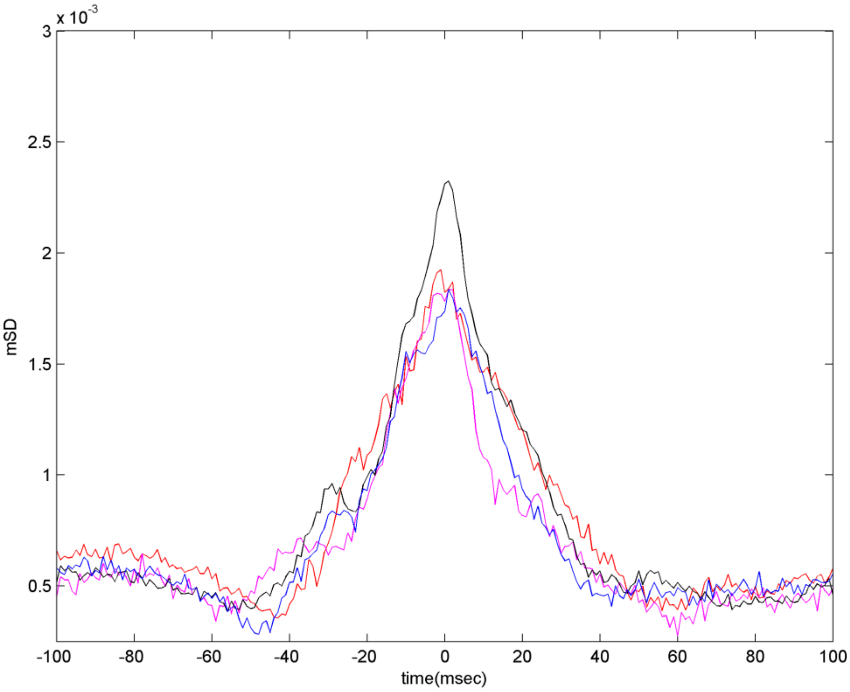

Figure 11.b) Unsuccessful shots per target (Acctotal)
(red:target 1, pink: target 2, black: target3, blue: target 4)

3.2.1.8 Response Time measurement

Response time was operationally defined as the time difference between the onset of light trigger signal and the point where the peak acceleration was reached at x-axis. Thus, response times were calculated for each shooting action by using synchronized recordings of acceleration and light trigger signals.

3.3. Data Analysis

Descriptive statistics (mean±, SD) were presented. Paired sample t-test was applied for differences between pre-fatigue and post-fatigue conditions in terms of shooting accuracy, ball speed and wrist acceleration. Regression analysis is used for determine the correlation accurate and inaccurate shot values together with shooting consistency, ball speed, acceleration of wrist at X,Y,Z axis.

CHAPTER IV

RESULTS

The independent variable of the study consisted of time (pre-fatigue and post fatigue). The dependent variables of the study were velocity, accuracy and movement pattern.

The descriptive statistics for HR, VO_2max, La, Running time and Running Velocity values acquired from treadmill and field tests were presented in Table 3.

Table 3. Descriptive Statistics of HR, VO_2max, LA, Running time and Running Velocity Values Acquired from Treadmill and Field Tests comparatively

Variables	Treadmill		Field Test	
	Mean	Std Dev.	Mean	Std Dev.
Max Heart Rate (bpm)	202.88	1.74	202.88	1.74
Running time (min)	23.33	2.93	13.48	1.31
Initial Velocity ($km^{-1}h$)	9	0	10.37	0.38
Ending Velocity ($km^{-1}h$)	14.75	0.85	16.59	0.87
Initial LA (mmol/L)	1.16	0.22	1.46	0.30
Ending LA (mmol/L)	7.21	1.60	6.68	1.34
Initial Heart Rate (bpm)	77.13	8.94	75.41	8.24
Ending Heart Rate (bpm)	190.38	6.57	191.75	9.47
Initial VO_2 (ml/kg/min)	31.64	6.21		
Ending VO_2 (ml/kg/min)	50.03	8.66	44.38	1.79
Optimum Shoot Vel ($km^{-1}h$)			77.60	5.69
Optimum Shoot Vel ($km^{-1}h$) %80			62.06	4.65

Results showed that running time in treadmill was sharply higher than running time in $30\text{-}15_{IFT}$ test. On the other hand, the values of ending LA and ending VO_2 in $30\text{-}15_{IFT}$ test were lower than treadmill test. In addition to these, HR was similar for both tests.

It was shown that shooting accuracy was not changed with fatigue condition. (Table 4).

Table 4. Paired sample t-test results for differences between accurate and inaccurate shots total points of handball players (n=16) during pre-fatigue and post-fatigue protocols.

Measurement	Mean	Sd	T	P
Accurate Pre-test	5.31	2.08	-.83	.415
Accurate Post-test	5.87	2.06		
Inaccurate Pre-test	10.68	2.08	.76	.459
Inaccurate Post-test	10.18	1.97		

Table 4 results showed that there was no significant differences between pre-fatigue and post-fatigue protocols in terms of accurate and inaccurate shots ($p>0,05$). According to this result, accurate and inaccurate shooting performance has not been affected by fatigue.

Results showed that inaccurate shots at the Y axis were affected by fatigue protocol (Table 5).

Table 5. Paired sample t-test results for significant differences among X, Y, Z axis values of wrist acceleration during shooting to target in pre-fatigue protocol and post-fatigue protocol.

Measurement	(msec)	Mean	Sd	T	p
Xpre-accurate	36.05	4.25	1.13	-1.40 -	.184
Xpost-accurate	37.24	3.87	1.03		
Xpre-inaccurate	36.11	3.71	.99	-1.76	.101
Xpost-inaccurate	37.35	4.19	1.11		
Ypre-accurate	33.25	4.63	1.23	-.62	.542
Ypost-accurate	33.81	3.82	1.02		
Ypre-inaccurate	33.12	4.40	1.17	-2.25	.042*
Ypost-inaccurate	34.50	4.56	1.21		
Zpre-accurate	3.43	1.67	.44	1.47	.163
Zpost-accurate	2.68	1.22	.32		
Zpre-inaccurate	3.45	1.30	.34	.54	.597
Zpost-inaccurate	3.22	1.31	.35		

*P<.05

According to Table 5 for X, Y, Z axis values of wrist acceleration during shooting to target before and after fatigue protocol; there was a significant difference on inaccurate shooting values at Y axis [t(15)= -2.25, p<0.05]. In light of the foregoing, fatigue protocol applied to players was affected accelerated motion at Y axis in the value of shooting accuracy. Accurate and inaccurate shots at the X and Z axis were not affected by fatigue protocol (p>0.05).

Ball speed in accurate and inaccurate shots were not affected by fatigue. (Table 6).

Table 6. Paired sample t-test for ball speed values between accurate (n=16) and inaccurate shots (n=16) before and after fatigue protocols.

Measurement	Mean	Sd	T	p
Accurate Pre-test	66.75	5.83	-.40	.693
Accurate Post-test	67.02	4.66		
Inaccurate Pre-test	66.94	5.95	-.76	.458
Inaccurate Post-test	67.48	4.48		

According to Table 6, there was no significant difference between before and after fatigue protocols in terms of ball speed in accurate and inaccurate shots ($p>0.05$). It is thought that ball speed in accurate and inaccurate shots were not affected by fatigue.

Shooting consistency has significant effects on shooting accuracy. Other variables have not important effects on shooting accuracy (Table 7).

Table 7. Results of regression analysis for prediction of accuracy points of handball players (n=16) before fatigue protocol (Mean=5.66±1.49).

Variables	B	Std Error	B	T	p	Part
Constant	-4.22	7.94		-.53	.617	
SCon (Mean=.0019±.0003)	4243.20	2045.42	.86	2.07	.043	.41
Ball speed (Mean=68.18±5.59)	.14	.12	.52	1.15	.301	-.19
Response time (Mean=1.28±.34)	1.58	1.30	.36	1.21	.278	.34
Xpre-accurate (Mean=36.40±4.11)	-.25	.15	-.69	-1.66	.157	-.31
Ypre-accurate (Mean=33.93±4.59)	-.03	.15	-.10	-.22	.831	-.41
Zpre-accurate (Mean=3.43±1.60)	.10	.35	.11	.29	.782	-.16
R=.78	R^2=.62					
$F_{(6,15)}$=1.37	p=.037					

Note: SCon= Shooting consistency

According to the results of Table 7 it was seen that, there was significant and high correlation in accurate shot values together with shooting consistency, ball speed, acceleration of wrist at X, Y, Z axis before fatigue protocol (R=.78, R2=.62). Variables which take placed above explained 62% of total variance.

According to standardized regression quotient, (β) relative priority of predictive variables on shooting accuracy; shooting consistency, exchange on X axis, ball speed, response time, exchange on Z axis and Y axis. When the results of t-test for significant of regression quotient it was seen that only variable of shooting consistency has significant effects on shooting accuracy. Other variables have not important effects on shooting accuracy.

Ball speed has significant effect on shooting inaccuracy (Table 8).

Table 8. Regression analysis results for prediction of inaccurate shots before fatigue protocol (Mean=10.78±1.88).

Variables	B	Std Error	Β	T	p	Part
Constant	32.16	8.24		3.90	.005	
SCon (Mean=.0021±.0004)	-2333.09	1208.89	-.52	-1.93	.442	-.04
Ball speed (Mean=67.26±4.87)	-.46	.12	-1.18	-3.65	.006	-.37
Xpre-inaccurate (Mean=36.11±3.71)	.27	.20	.45	1.34	.217	.21
Ypre-inaccurate (Mean=33.12±4.40)	.08	.23	.20	.37	.718	.18
Zpre-inaccurate (Mean=3.45±1.30)	.44	.52	.30	.83	.428	.06
R=.80	R^2=.64					
$F=_{(6,15)}=2.90$	p=.038					

Note: SCon= Shooting consistency

Table 8 showed that, there is a significant and high correlation in inaccurate shots values together with shooting consistency, ball speed, acceleration of wrist at X, Y, Z axis of handball players before fatigue protocol (R=,80 R^2= .64). Variables that are mentioned above explained 64% of total variance.

According to standardized regression quotient (β), relative priority of predictive variables on shooting accuracy; ball speed, shooting consistency, exchange at X axis, exchange at Z axis, and exchange at Y axis. When the results of t-test for significant of regression quotient examined it was seen that ball speed have significant effect on shooting inaccuracy. Other variables have no effects on shooting inaccuracy.

None of variables affected accurate shot values (Table 9).

Table 9. Regression analysis results for accurate shots after fatigue protocol (Mean= 6.25±1.91).

Variables	B	Standard Error	Β	T	p	Part
Constant	29.73	13.48		2.20	.079	
SCon (Mean=0022±0005)	-1022.74	1601.59	-.29	-.63	.551	-.16
Ball speed (Mean=68.05±4.48)	-.15	.15	-.37	-1.05	.340	-.63
Response time (Mean=1.33±50)	-.13	.20	-.28	-.67	.529	-.56
Xpost-accurate (Mean=37.12 ±3.97)	.07	1.74	.02	.04	.966	.44
Ypost-accurate (Mean=33.36 ±3.33)	-.16	.24	-.28	-.65	.540	-.65
Zpost-accurate (Mean=2.59 ±1.23)	.00	.74	.00	.00	.994	-.15
R= .79	R^2=.63					
$F=_{(6,15)}$=1.46	p=.034					

Note: SCon= Shooting consistency

Table 9 showed that, there is a significant and high correlation in accurate shot values, together with shooting consistency, response time, ball speed, acceleration of wrist at X, Y, Z axis after fatigue protocol (R=.79, R^2=.63). Variables that are mentioned above explained 63% of total variance.

According to standardized regression quotient (β), relative priority of predictive variables on shooting accuracy; ball speed, shooting consistency, response time, and exchange at Y axis, exchange at X axis, and exchange at Z axis. When the results of t-test for significant of regression quotient examined, none of variables have important effects on accurate shot values.

None of variables affected inaccurate shot values (Table 10).

Table 10. Regression analysis results for inaccurate shots after fatigue protocol (Mean= 10.53±1.85).

Variables	B	Std Error	B	T	p	Part
Constant	2.43	9.44		.25	.804	
SCon (Mean=.0022±00)	.06	.14	.17	.44	.668	.31
Ball speed (Mean=67.65±4.74)	-139.61	1513.74	-.03	-.09	.929	.06
Xpost-inaccurate (Mean=37.72±4.11)	-.19	.27	-.44	-.73	.489	.16
Ypost-inaccurate (Mean=35.25±3.73)	.31	.32	.64	.99	.352	.36
Zpost-inaccurate (Mean=3.32±1.32)	.05	.50	.04	.11	.915	.08
R= .46	R^2=.21					
$F=_{(6,15)}=.38$	p=.023					

Note: SCon= Shooting consistency

In Table 10 it is seen that, there is significant and moderately correlation in inaccurate shot values together with shooting consistency, ball speed, acceleration of wrist at X,Y,Z axis after fatigue protocol (R=.46, R^2=.21). Variables that are mentioned above explained 21% of total variance.

According to standardized regression quotient (β), relative priority of predictive variables on shooting accuracy; exchange at Y axis, exchange at X axis, shooting consistency, exchange at Z axis and ball speed. When the results of t-test for significant of regression quotient examined it was seen that none of variables have important effects on accurate shot values.

CHAPTER V

DISCUSSION

The aim of this study was is to investigate the effects of muscle fatigue on shooting accuracy in male handball players. The study also attempted to examine the effects of muscle fatigue on ball speed and wrist acceleration. In addition, difference between accurate and inaccurate shots in terms of ball speed was another research question. Further, this study also aimed to investigate the correlation between ball speed, wrist acceleration, movement pattern and shooting accuracy during shots and differences between accurate and inaccurate shots in terms of movement pattern.

When the laboratory tests and field tests are compared with each other in terms of running time, the values of La and VO_2 at the end of tests, it was found that running time in treadmill was longer than field test but running speed at the end was higher in $30\text{-}15_{IFT}$. The difference of running time between two tests can be explained by dynamics of running type. While treadmill test was a continuous and straight-line running, $30\text{-}15_{IFT}$ was intermittent shuttle run rest. In addition, in treadmill test, initial velocity of all participants' were same ($9km^{-1}h$) but in $30\text{-}15_{IFT}$ initial velocity of the test were different according to their percentage of vVO2max values obtained from treadmill test. In this situation some participant started to test from 10 $km^{-1}h$, on the other hand some of them started from 11 $km^{-1}h$. Thus, running time was short but intensity was high in $30\text{-}15_{IFT}$ as against treadmill test. From this point, it was seen that intermittent shuttle exercise was more intensive than in-line running because of the nature of shuttle which contains fast running and returns as the similar to handball game.

When it was compared the laboratory or field test, there were another results related to La, VO_2 and HR responses. While La and VO_2 were lower in 30-15_{IFT} (6.68±1.34mmol/L) than treadmill test and La values ranging from 4.04 to 9.50mmol/L. Michalsik et al. were reported La values before the match, after half time and at the end of the matched were 1.49±0.46mmol/L, 3.73±1.59mmol/L and 4.82±1.89mmol/L respectively, with individual post match values ranging from 2.84 to 10.81mmol/L. Furthermore, there were no significant differences between treadmill and 30-15_{IFT} in terms of HR responses. In male players mean heart rate during a whole match was reported between 75-80 % maximum heart rate (Platen, 2011; Chrosa,1999).

As an contrasting results to current study, when Dellal et.al (2010) reported that HR and La were significantly higher when intermittent exercise at the same intensity was performed in shuttle format compared with traditional in line running, Zadro et.al. (2011) reported that the values of La at the end of the intermittent test were indeed significantly reduced after specific training. As a result, endurance protocols administered in laboratory and field conditions caused different physiological strain at submaximal and maximal speeds Aslan,2011).

From this point, it was seen that, because of the intensive and intermittent nature of 30-$15_{IFT,}$ there were intensive eccentric contraction with negative acceleration, changing intermittent direction and positive acceleration respectively. In 30-$15_{IFT,}$ there were 15 seconds resting periods after every 30 second loading periods so metabolism could showed a certain time recovery during the all resting times of shuttle. So that it affects the metabolic responses of participants and they exhausted early than treadmill.

As a supportive study Chamari et.al (2004) reported that La at maximal intensity exercise in treadmill was (11.6mmol/L) higher than field test (9mmol/L). Besides testing time in treadmill was higher than field test like current study. Haydar et al. (2011), compared original 30-15_{IFT} and three modified protocols including either no rest (continuous) period, no change of direction ability (COD) or a greater number of COD (28m). As a result of study, it was reported that, there were no differences between tests. La was lower for 30-15$_{IFT-CONT,}$ Compared with 30-15$_{IFT,}$ maximal running speed was higher for 30-15$_{IFT-LINE}$ and lower for 30-15$_{IFT-CONT,}$ similar with 30-15$_{IFT-COD.}$

Contrasting findings were also obtained from the studies of Aslan et al. (2011). They compared various endurance protocols such as treadmill, shuttle run, circular shuttle run, modified shuttle run tests in terms of their metabolic responses and they stated that, La responses to submaximal running until 10km^{-1}h were similar but over 10km.$^{-1}$h speed, La concentration at modified shuttle and circular shuttle run higher than treadmill test. It was reported also, VO2max values at all running speeds similar with shuttle and modified shuttle run tests. However, VO2 at running speed between 9 -13 km.$^{-1}$h were higher treadmill test lower than shuttle and modified shuttle run and higher than circular shuttle run and modified circular shuttle run tests. In another study belongs to Edis et al. (2008) were compared field and laboratory tests in terms of physiological responses to submaximal and maximal exercise intensities in young soccer players. They were reported that although resting La and resting HR similar during both tests, peak La at laboratory were found significantly lower than field test and during the laboratory tests, and duration of test is higher in laboratory than field test. In our study, there was a contrasting result related with La responses so, peak La at laboratory was found higher than field test.

These differences could be done because of the environmental factors such as temperature, floor, running mechanism depends on test equipment which are used in test or sports branches of participants could be effective for create differences between laboratory and field tests. The studies were mentioned above were on soccer players but we studied on handball players.

While setting the fatigue protocol, it was used 75% of VO_2 max values of each participant in order to set relative fatigue protocol for each player in contemplation of being conditional differences of players. Michalsik et al (2011), stated relative work load during match-play on average 70.85±6.00 % of VO_2max for elite team handball players and they also added individual variations in relative work load were observed, since players showed transient periods with a relative work load corresponding over 90 % of VO2max, while at other times they performed with a load below 50 % of VO_2max.

As a results of current study it was determined the mean values of VO_2max as 50.03 ±8.66 ml/kg/min in treadmill test and 44.38 ±1.79 ml/kg/min in field test. Many researches in literature were reported VO2max values of male handball players such as 55.23±4.12ml/kg/min (Michalsic et al, 2011a), 50.41±4.60 ml/kg/min, 47.5±4.8 (Michalsic et al, 2011b).

The main result of this study was there were no significant differences between pre-fatigue and post-fatigue protocols in terms of accurate and inaccurate shots. In other words, accurate and inaccurate shooting performance has not been affected by fatigue. According to related literature about match profiles of team handball, effective playing time for the whole match was reported approximately over 70% of total effective playing time (Michalsik, 2011) and number of attack (57.5±3.8) and mean time of one attack (23.0±1.9sec.) were reported (Platen et al., 2011) also. From that point, it can be explained that players have to shot many times during the whole match accurately and without being obstructed by the opposing defensive players and they also have to cope with fatigue as a result of highly intensive game situation. In that conditions, coaches and players have been designed and performed such a training that combined all these factors mentioned above directly related to success. So a team-handball player has to perform various kinds of shots many times in training sessions even though more than competition condition. If it was thought that players always suffer from fatigue both in training and match environment with different levels of intensity. In addition to learning effects of test procedures, players accustomed to fatigue conditions to both training and match environments could be reason not to affect from fatigue in shooting accuracy. Enoka (1995) was reported that unless athletes were highly motivated, most individuals terminate exercise before their muscles are physiologically exhausted so elite athletes highly motivates themselves especially for match condition and although they reached fatigue in a way they can continue their performance at top as long as possible.

Silva et al. (2004) reported that the standing shooting performance was not affected by fatigue as a supporter study. Uygur et al. (2010) also supported the current study and the results of their study demonstrated that, fatigue did not affect free throw shooting kinematics in collegiate level basketball players.

Wrist motion at Y axis was increased for inaccurate shots after fatigue protocol [$t(15)= -2,259$, $p<0,05$]. However X and Z axis were not affected by fatigue for inaccurate shots.

Present results showed that, there were no changes in ball speed values between pre and post fatigue protocols. Throwing ball velocity in team handball is a very important component contributing to the success of the game (Zapartidis, 2009). There are many studies about shooting velocity in team handball and set shot velocities were represented 92,8±5,3 km.h^{-1} (Michalsik et al, 2011), 83.5±7.8 km.h^{-1}; 88.4±8.2 km.h^{-1} (Pori,2011), 70.72±7.0 (Zapartidis, 2009).

Laffaye (2011) stated that the time allotted to ball throwing velocity is a large part of the training program and coaches based their training program on an accurate analysis of the ball throwing technique. Because of these training programs allows a gain velocity of 2 to 6.9 %. Van den Tillar (2004) advised that throwing velocity could be enhanced only if the training program consists of at least three trainings per weeks for five weeks, to be efficient, the training program based on individual parameters such as players' experience.

According to the results of pre-fatigue conditions; while there was seen significant and high correlation (R=,789, R^2=,622) in accurate shots (Variables explained 62% of total variance). Shooting consistency has an effect on accurate shots. Also there was also seen significant and high correlation (R=,803 R^2= ,645) in inaccurate shots (Variables explained 65% of total variance) together with shooting consistency, ball speed, acceleration of wrist at X, Y, Z axis. Ball velocity has effect on inaccurate shots.

According to the results of post-fatigue conditions; while there was seen significant and high correlation (R=,798, R2=,637) in accurate shots (Variables explained 64% of total variance). None of variable has effect on accurate shots. There was also seen significant and moderately correlation (R=,465 R^2= ,217) in inaccurate shots (Variables explained 22% of total variance) together with shooting consistency, ball speed, acceleration of wrist at X, Y, Z axis. None of variable has effect on inaccurate shots

It was observed that shooting consistency and ball velocity have important role in shooting accuracy in pre-fatigue conditions. In other words, when players use similar kind of shooting technique, it was seen an increase at accuracy level and when players use faster shots it was seen decrease in accuracy level. This situation was not a surprised and it can be explained by Fitts' law suggested that there was a trade between speed and accuracy. When speed is emphasized, accuracy is reduced (Kluka, 1999). In the post-fatigue condition, none of variable affects accuracy. Players should maintain the potential of the optimal output in ball velocity and accuracy in shooting during the game and reported data refers that throwing effectiveness is significantly affected by time, as aiming accuracy gradually decreases (Zapartidis et al, 2007).

On the other hand, the acceleration of wrist showed a difference between pre-fatigue and post-fatigue conditions. In pre-fatigue conditions, right to left motion of wrist (X axis) was the most important motion, then Z axis (up to down) and Y axis (back to forward) accompanied respectively. However, after fatigue condition, priority of X and Y axis was changed places and back to forward motion (y axis) was became more important than right to left motion. Players were tent to change their throwing movement and did back to forward motion more forcefully than right to left motion as a result of fatigue condition. It can be explained by players should be preferred performing movement more easily or economically. Although the effects of fatigue reaching goal could be easiest after fatigue condition.

This study was limited to whole body fatigue protocol, it is recommended that research set up can be performed by using local fatigue protocol consist of sport specific movement.

CHAPTER VI

CONCLUSION

There were many researches which were aimed to develop performance. Shooting effectiveness and accuracy are the critical points of performance in team handball for reaching best result. Current study investigated the effects of fatigue on shooting accuracy.

At the end of the study, as a main result, no significant differences were found between pre-fatigue and post-fatigue protocols in terms of accurate and inaccurate shots.

According to the results shooting consistency, ball speed, response time, X, Y, Z axis of wrist acceleration variables highly correlated each other in terms of shooting accuracy both in pre and post fatigue conditions. Shooting consistency has an effect on accurate shots. Ball velocity has effect on inaccurate shots in pre-fatigue condition. However, none of variable has effect on accurate and inaccurate shots in post-fatigue conditions.

On the other hand, the acceleration of wrist showed a difference between pre-fatigue and post-fatigue conditions. In pre-fatigue conditions, right to left motion of wrist (X axis) was the most important motion, back to forward motion (y axis) was became more important in post fatigue condition.

REFERENCES

American College of Sports Medicine (ACSM). 2000. *ACSM's guidelines for exercise testing and prescription.* 6th ed. Philadelphia: Lea&Febiger.

Aslan, A., Güvenç, A., Hazır, T., Aşçı, A., Açıkada, C. (2011). Comparison of metabolic responses to various endurance protocols. *Hacettepe Journal of Sports Sciences.* 22(3), 124-138.

Armstrong, N. (1998). Young people's physical activity patterns as assessed by heart rate monitoring. *Journal of Sport Sciences*. 16, 9-16.

Arpinar-Avsar P., Soylu AR. (2010). Consistency in acceleration patterns of football players with different skill levels. *Journal of Sports Science and Medicine* 9, 382-387.

Belli, T., Ackermann, M.A., Riberio, L.F., Langeani, R., Galdino, S.R., Baldissera, V. (2007). Lactate and ventilatory threshold in type 2 diabetic women. *Diabetes Res Clin Pract.* 76(1), 17-23.

Bourne, M., Bennett, S.J., Hayes, S.J., Williams, A.M. (2011). The dynamical structure of handball penalty shots as a function of target location. *Human Movement Sciences.* 30, 40-55.

Buchheit, M. (2008). The 30-15 intermittent fitness test: accuracy for individualizing interval training of young intermittent sport player. *Journal of Strength and Conditioning Research* 22(2), 365-74.

Buchheit, M., Laursen, P.B., Kuhnle, J., Ruch, D.,Renaud, C., Ahmaidi, S. (2009). Game-based training in young elite handball players. Int. *J.Sports Med* 30, 251-58.

Buchheit, M., Lepretre, P.M., Behaegel, A.L., Millet, G.P., Cuvelier, G., Ahmaidi, S. (2009). Cardiorespiratory responses during running and sport specific exercises in handball players. *J Sci Med Sport* 12, 399-405.

Buchheit, M., Villanueva, A.M., Quod; M., Quesnel, T., Ahmaidi, S. (2010). Improving acceleration and repeated sprint ability in well trained adolescent handball players: Speed versus sprint interval training. *International Journal of Sports Physiology and Performance.* 5, 152-164.

Ceesay, S.M., Prentice, A.M., Day, K.C., Murgatroyd, P.R., Godberg, G.R., Scott, W. (1989). The use of heart rate monitoring in the estimation of energy expenditure: A validation study using indirect whole body calorimetry. *British Journal of Nutrition.* 61, 175-86.

Chelly, M.S., Hermassi, S., Aouadi, R., Khalifa, R., Tillar, R.V.D., Chamari, K., Shephard, R.j. (2011). Match analysis of elite adolescent team handball players. *Journal of Strength and Conditioning Research.* 25(9), 2410-17.

Clanton, R.E., Dwight, M.p. (1997). *Team Handball Steps to Success. Human Kinetics Publishers*, Inc., USA.

Chamari, K., Hachana, Y., Ahmed, Y.B., Galy, O., Sghaier, F., Chatard, J.C., Hue, O. And Wisloff, U. (2004). Field and laboratory testing in young elite soccer players. *Br J Sports Med*., 38, 191-196.

Delamarche, P., Gratas, A., Beillot, J. Dassonville, J., Rochcongar, P., Lessard, Y. (1987). Extent of lactic anaerobic metabolism in handballers. *Int J Sports Med* 8, 55-59.

Dellal, A., Keller, D., Carling, C., Chaouachi, A., Wong, D.P., Chamari, K. (2010). Physiologiceffects of directional changes in intermittent exercise bin soccer players. *Journal of Strength and Conditioning Research.* 24(12), 3219-26.

Demarie, S., Koralsztein, JP, Billat, V.(2000). Time limit and time at VO2max during a continuous and an intermittent run. *J. Sports Med Phys Fitness*. 40, 96-102.

Edis, Ş.E., Hazır, T., Şahin, Z., Hazır, S., Aşçı, A., Açıkada, C. (2007). Physiological responses to submaximal and maximal exercises intensities: field versus laboratory. *Hacettepe J. Of Sports Sciences.* 18(2),57-67.

Enoka, R.M. (1995). Mechanism of muscle fatigue: Central factors and task dependency. J. Electromyogr Kinesiol. 5(3), 141-49.

Fox, E.L., Bowers, R.W., Foss, M.L. (1988). *The physiological basis of physical education and athletics.* Philadelphia: Saunders College Publishing. pp:36.

Fradet, L., Botcazou, M., Durocher, C., Cretual, A., Multon, F., Prioux, J. (2004). Do handball throws always exhibit a proximal to distal segment sequence? *Journal of Sport Sciences*. 5, 439-47.

Freedson, P.S., Miller, K. (2000). Objective monitoring of physical activity using motion sensors and heart rate. *Research Quarterly for Exercise and Sport.* 71, 21-9.

García, J.R., Navarro, F., Grande, I., Ignatova, A.S., Sampedro, J. (2010) Differences in throwing capasity between senior and U18 handball players. *Serbian Journal of Sports Sciences*. 4,145-51.

Ghosh, A.K. (2004). Anaerobic Threshold: Its concept and role in endurance sport. *Malaysian Journal of Medical Sciences* 11(1), 24-36.

Gorostiaga,E.M., Granados, C., Ibanez, J., Gonzalez-Badillo, J.J., Izquierdo, M. (2006). Effects of and entire season on physical fitness changes in elite male handball players. *Med Sci Sports Exerc* 38, 357-66.

Granados, C., Izquierdo, M., Ibañez, H.Bonnabau, E., Gorostiaga, M. (2007). Differences in physical fitness and throwing velocity among elite and amateur female handball players. *Int J Sports Med.* 28, 850-67.

Haydar, B., Haddad, H.A., Ahmaidi, S., Buchheit, M. (2011). Assessing inter effort recovery and change of direction ability with the 30-15 Intermittent Fitness Test. *Journal of Sport Science and Medicine*. 10, 346-54.

Hellemans, J. (1993). A complete guide to training and racing. *Medicine and Science in Sport and Exercise* 33(1), 152-56.

Hoff, J., Almasbakk, B. (1995). The effects of maximum training on throwing velocity and muscle stregth in female team-handball players. *J Strength Cond Res* 9, 255-58.

Housh, T.J., Housh, .D.J., Devries, H.A. (2003). *Applied Exercise and Sport Physiology*. Holcomb Hathaway, Publishers, Inc., Arizona.

Hurley, B.F., Seals, D.R., Ehsani, A.A., Cartier, L.J., Dalsky, G.P., Hagberg, J.M., Holloszy, J.O. (1984). Effects of high intensity strength training on cardiovascular function. *Medicine and Science in Sports and Exercise*. 16, 483-88.

Janz, K.F. (2002). Use of heart rate monitors to assess physical activity. G.J. Welk, (Ed). *Physical activity assessment for health related research*. pp;143-58. USA: Human Kinetics.

Kay, D., Gibson, A., Mitchel, M.J., Lambert, M.I., Noakes, T.D. (2000). Different neuromuscular recruitment patterns during eccentric, concentric and isometric contractions. *J. Electromyogr Kinesiol*. 10, 425-31.

Kluka, D.A. (1999). *Motor Behavior From Learning to Performans*. Morton Publishing Company,USA.

Laffaye, G., Debanne, T. (2011). Training programs used by french professional coaches to increase ball throwing velocity of elite handball players. *In pocedings of the EHF Scientific Conference*. 18-19 November 2011. Vienna, Austria, pp. 273-78.

Marques, M., González-Badillo, J. (2006). In-seasons resistance training and detraining in professional team handball players. *J Strength Cond Res*., 20(3), 563-571.

Marrow, J.R., Jackson, A.W., Disch, J.g., Mood, D.P. (2005). *Measurement and evaluation in human performance.* 3rd edition. Human Kinetics, USA. pp 227-230.

Michalsik, L.B., Aagaard, P., Madsen, K. Match performance and physiological capacity of male team handball players. *In pocedings of the*

EHF Scientific Conference. 18-19 November 2011. Vienna, Austria, pp.168-73.

Michalsik, L.B., Madesn, K., Aagard, P., K. Activity match profile and physiological demands in female elite team handball. *In pocedings of the EHF Scientific Conference.* 18-19 November 2011. Vienna, Austria, pp.162-67.

Midgley, A. W., McNaughton,L.R., Carroll, S. (2007). Time at VO2max during intermittent treadmill running: Test protocol dependent or methodological artefact? *Int J Sports Med*. 28, 934-39.

Nieman, D.C. (1999). Exercise testing and prescription: A health related approach. *Mountain View*, CA: Mayfield Publishing.

Platen, P., Manchado, C. (2011). Basic endurance performance is highly correlated to mean heart rate in female top level handball players. *In pocedings of the EHF Scientific Conference.* 18-19 November 2011. Vienna, Austria, pp.290-92.

Pori, P., Boni M., Sibila, M. (2005). Jump shot performance in team handball: A kinematic model evaluated on the basis of expert modelling. *Kinesiology.* 37(1), 40-49.

Rannau, F., Prioux, J., Zouhal, H., Gratas-Delamarche, A., Delamarche, P. (2001). Physiological profile of handball players. *J Sports Med Phys Fitness* 41, 349-53.

Robergs, R.A. (1996). Exercvise physiology: *Exercise, performance and clinical applications.* St. Louis Mosby year-Book.

Rowlands, A.V., Eston, R.G., Ingledew, D.K. (1997). Measurement of physical activity in children with particular referenceto the use of heart rate and pedometry. *Sports Medicine*. 24, 258-72.

Royal, K.A., Farrow, D., Mujika, I., Halson, S.L., Pyne, D., Abernethy, B. (2006). The effects of fatigue on decision making and shooting skill performance in water polo players. *Journal of Sport Science*. 24 (8), 807-15.

Shephard, R.J. (1992). Maximal oxygen intake. Shephard R.J-Astrand, P.O. (Eds) Enduranse in Sport (pp 192-200) USA. Blackwell Scientific Publication.

Skarbalius, A. Monitoring Sport performance in Handball. *In pocedings of the EHF Scientific Conference.* 18-19 November 2011. Vienna, Austria, pp. 325-330.

Schmidt, R.A., Wrisberg, C.A. (2004). Motor learning and performance: A problem-based learning approach (3rd ed). Human Kinetics, Champaign, IL. pp 155-179.

Swain, D.P., Leutholtz, B.C. (1997). Heart rate reserve is equivalent to % VO_2 reserve not to % VO_2max. *Medicine and Science in Sports and Exercise*. 29, 410-14.

Turkish Handball Federation (THF), International game rules (2010). http://www.thf.gov.tr/ files/internationalhandballgamerules.PDF

Uygur, M., Göktepe, A. Ak, E., Karabörk, H., Korkusuz, F. (2010). The effect of fatigue on the kinematics of free throw shooting in basketball. *Journal of Human Kinetics.* 24, 51-56.

Uzun, S. (2002). *Fatigue related EMG power spectrum changes during dynamic contractions in female rowers.* Unpublished Master dissertation, Boğaziçi University.

Van den Tillaar, R., Ettema, G. (2003). Influence of instruction on velocity and accuracy of overarm throwing . *Percept Mot Skills.* 96, 423-34.

Van den Tillaar, R., Ettema, G. (2004). Force velocity relationship and coordination patterns in overarm throwing. *Journal of Sports Science and Medicine.* 3, 211-19.

Van den Tillar, R. and Ettema, G. (2007) A Three-Dimensional Analysis of Overarm Throwing in Experienced Handball Players. *Journal of Applied Biomechanics* 23, 12-19.

Wagner, H., Müller, E. (2008). The effects of differential and variable training on the quality parameters of a handball throw. *Sports Biomechanics*. 7(1), 54-71.

Wagner, H., Pfusterschmied, J., Duvillard, S.P., Müller, E. (2011). Performance and kinematics of various throwing techniques in team-handball. *Journal of Sports Science and Medicine*. 10, 73-80.

Wareham, N.J., Hennings, S.J., Prentice, A.M., Day, N.E. (1997). Feasibility of heart rate monitoring to estimate the Ely young cohort feasibility study 1994-1995. *British Journal of Nutrition*. 78, 889-900.

Washington, R:L: (1999). Cardiorespiratory testing: Anaerobic threshold/respiratory threshold. *Pediatr Cardiol*. 20,12-15.

Zapartidis, I., Gouvali, M., Bayios, I., Boudolos, K. (2007). Throwing effectiveness and rotational strength of the shoulder in team handball. *J Sports Med Phys Fitness*. 47, 169-178.

Zapartidis, I., Vareltzis, I., Gouvali, M., Kororos, P. (2009). Physical fitness and antropometric characteristics in different levels of young team handball players. *The Open Sports Sciences Journal*. 2, 22-28.

Zapartidis, I., Toganidis, T., Vareltzis, I., Christodoulidis, T., Kororos, P., Skoufas, D. (2009). Profile of young female handball players by playing position. *Serbian Journal of Sports Sciences* 3(1-4), 53-60.

Zech, A., Steib, S., Hentschke, C., Eckhardt, H., Pfeifer, K. (2012). Effects of localized and general fatigue on static and dynamic postural control in male team handball athletes. *Journal of Strength and Conditioning Research*. 26(4), 1162-68.

APPENDICES

APPENDIX A

GÖNÜLLÜ KATILIM (BİLGİLENDİRİLMİŞ ONAY) FORMU

Değerli katılımcı;

Bu çalışma Orta Doğu Teknik Üniversitesi Beden Eğitimi ve Spor Bölümü Egzersiz Fizyolojisi Anabilim Dalı Doktora programı bitirme tezi kapsamında yapılacak olup çalışmada, kas yorgunluğunun hentbol oyuncularının şut isabetine etkisinin incelenmesi amaçlanmıştır.

Çalışmada, yorgunluk protokolü öncesi, yorgunluk protokolü ve yorgunluk protokolü sonrası uygulamalar yapılacaktır. Uygulamalar iki bölümden oluşacak ve bu bölümler katılımcıya uygun olan iki farklı günde yapılacaktır. Her bölümün süresi, sporcuların kondisyon durumuna bağlı olarak değişiklik göstermekle birlikte yaklaşık 30 dakika olmak üzere toplam süre yaklaşık 60 dakika olarak tahmin edilmektedir. Yorgunluk öncesi test protokolünde, sporcular gaz analizörü bağlı olan bir koşu bandına alınacaklar ve yüze gaz analizörünün maskesi, göğse nabız ölçer saate ait göğüs bandı ile kola nabzın takip edileceği nabız ölçer saat takılacaktır. Katılımcılar 8km/saat hızla koşu bandında koşmaya başlayacak ve her 3 dakikada koşu bandı durdurularak hız 1km/saat artırılacaktır. 3 dakikalık sürelerin bitimindeki her arada başlangıçta lanset ile bir kez delinecek olan kulak memesinden 25 µl miktarında kan alınacaktır. Kulak memesinden kan alım işlemi sırasında katılımcı acı hissetmeyecektir. Alınan kan, hiç bekletilmeden ve başka herhangi bir işlem görmeden, işlenmesi için bir laktik asit analizörüne nakledilerek sporcuların laktat eşikleri tespit edilecek, böylece sporcuların yorgunluğa ulaştıkları nokta belirlenecektir. Sporcular tükendiklerini hissettikleri zaman koşmayı bırakacaklardır. Bu zaman zarfında koşu bandına bağlı gaz analizörü tarafından sporcuların oksijen tüketim kapasiteleri saptanacak ve üzerlerine takılı olan kalp atım hızı monitörü vasıtasıyla da kalp atım hızları takip edilecektir. Bu bölümden elde edilecek olan verilerden yola çıkarak her sporcuya kendilerine ait bireysel yorgunluk protokolü oluşturulacaktır.

İkinci uygulama gününde öncelikle sporcular standart hentbol kalesine, 3 numara hentbol topu ile 5 kez hedef olmaksızın şut atacaklar, buradan maksimal atış hızı, el bileği ve dirsekteki referans noktalarına bağlanmış olan bir ivme ölçer vasıtasıyla atış sırasındaki kolun ivmelenmesi belirlenecektir. Sonrasında sporcular kendileri için hazırlanmış olan yorgunluk protokolü çerçevesinde mekik koşusu koşmaya başlayacaklardır. Tükendikleri zaman koşuyu bırakacaklar ve hemen akabinde 1 kez yapılacak olan laktik asit ölçümü biter bitmez şut atışlarına geçeceklerdir. Sporcular kalenin dört köşesinde yer alan 50X50 cm boyutundaki hedeflere maksimal hızla dörder defa ve rastgele sıralamayla atış yapacaklar (toplam 16 atış), atışlar esnasında kolun ivmelenmesi ve topun hızı ölçülecektir.

Çalışma sonrasında elde edilecek verilerden yola çıkılarak hentbol sporunda başarıya ulaşmada önemli rol oynayan şut isabetinin, atış hızının ve kolun ivmelenmesiyle ortaya çıkan hareket paterninin yorgunluktan ne kadar etkilendiği ve sporcunun atış tekniğini etkileyip etkilemediği belirlenerek yapılacak olan antrenman programlarına ışık tutacağı kanaatindeyiz.
Çalışma süresince katılımcılar hiçbir surette potansiyel bir riske maruz kalmayacaklardır. Ayrıca çalışmaya katılım gönüllülük esasına dayalıdır ve katılımcı istediği zaman her hangi bir sebep göstermeksizin araştırmadan çekilebilir ve böyle bir durumda her hangi bir olumsuz sonuçla karşılaşmaz. Katılımcıların kişisel bilgileri ve çalışma esnasında çekilecek video görüntüleri özenle korunacak ve çalışma dışında herhangi bir yerde kullanılmayacaktır.

Gönüllünün beyanı:

Araştırmacı Beyza ŞİMŞEK tarafından Orta Doğu Teknik Üniversitesi Beden Eğitimi ve Spor Bölümü Egzersiz Fizyolojisi Anabilim Dalı Doktora programı bitirme tezi kapsamında bir araştırma yapılacağı belirtilerek bu araştırma ile ilgili yukarıdaki bilgiler bana aktarıldı. Bu bilgilerden sonra böyle bir araştırmaya "katılımcı" (denek) olarak davet edildim.

Eğer bu araştırmaya katılırsam araştırma sonuçlarının bilimsel amaçlarla kullanımı sırasında kişisel bilgilerimin özenle korunacağı konusunda bana yeterli güven verildi.

Çalışmanın yürütülmesi sırasında herhangi bir sebep göstermeden araştırmadan çekilebilirim. (Ancak araştırmacıları zor durumda bırakmamak için araştırmadan çekileceğimi önceden bildirmemim uygun olacağının bilincindeyim) Bu araştırmaya gönüllü olarak katılıyorum. Araştırmaya katılmam konusunda zorlayıcı bir davranışla karşılaşmış değilim. Eğer katılmayı reddedersem, herhangi bir olumsuz sonuçla karşılaşmayacağımı biliyorum. Araştırmayla ilgili herhangi bir sorun yaşarsam bahsi geçen araştırmacıyla iletişime geçebileceğimi biliyorum.

Bana yapılan tüm açıklamaları ayrıntılarıyla anlamış bulunmaktayım. Bu araştırmada "katılımcı" (denek) olarak yer alma kararını aldım. Bu konuda yapılan daveti gönüllülük içerisinde kabul ediyorum.

Ad-Soyad Tarih İmza

-------/--------/------

APPENDIX B

EBEVEYN ONAY FORMU

Veli Onay Mektubu

04.08.2012

Sayın Veli,

Orta Doğu Teknik Üniversitesi, Beden Eğitimi ve Spor Bölümünde doktora öğrencisiyim. Bu çalışma Orta Doğu Teknik Üniversitesi Beden Eğitimi ve Spor Bölümü Egzersiz Fizyolojisi Anabilim Dalı Doktora programı bitirme tezi kapsamında yapılacak olup çalışmada, kas yorgunluğunun hentbol oyuncularının şut isabetine etkisinin incelenmesi amaçlanmıştır.

Çalışmada, yorgunluk protokolü öncesi, yorgunluk protokolü ve yorgunluk protokolü sonrası uygulamalar yapılacaktır. Uygulamalar iki bölümden oluşacak ve bu bölümler katılımcıya uygun olan iki farklı günde yapılacaktır. Her bölümün süresi, sporcuların kondisyon durumuna bağlı olarak değişiklik göstermekle birlikte yaklaşık 30 dakika olmak üzere toplam süre yaklaşık 60 dakika olarak tahmin edilmektedir. Yorgunluk öncesi test protokolünde, sporcular gaz analizörü bağlı olan bir koşu bandına alınacaklar ve yüze gaz analizörünün maskesi, göğse nabız ölçer saate ait göğüs bandı ile kola nabzın takip edileceği nabız ölçer saat takılacaktır. Katılımcılar 8km/saat hızla koşu bandında koşmaya başlayacak ve her 3 dakikada koşu bandı durdurularak hız 1km/saat artırılacaktır. 3 dakikalık sürelerin bitimindeki her arada başlangıçta lanset ile bir kez delinecek olan kulak memesinden 25 µl miktarında kan alınacaktır. Kulak memesinden kan alım işlemi sırasında katılımcı acı hissetmeyecektir. Alınan kan, hiç bekletilmeden ve başka herhangi bir işlem görmeden, işlenmesi için bir laktik asit analizörüne nakledilerek sporcuların laktat eşikleri tespit edilecek, böylece sporcuların yorgunluğa ulaştıkları nokta belirlenecektir. Sporcular tükendiklerini hissettikleri zaman koşmayı bırakacaklardır. Bu zaman zarfında koşu bandına bağlı gaz analizörü tarafından sporcuların oksijen tüketim kapasiteleri saptanacak ve üzerlerine takılı olan kalp atım hızı monitörü vasıtasıyla da kalp atım hızları takip edilecektir. Bu bölümden elde edilecek olan verilerden yola çıkarak her sporcuya kendilerine ait bireysel yorgunluk protokolü oluşturulacaktır.

İkinci uygulama gününde öncelikle sporcular standart hentbol kalesine, 3 numara hentbol topu ile 5 kez hedef olmaksızın şut atacaklar, buradan maksimal atış hızı, el bileği ve dirsekteki referans noktalarına bağlanmış olan bir ivme ölçer vasıtasıyla atış sırasındaki kolun ivmelenmesi belirlenecektir. Sonrasında sporcular kendileri için hazırlanmış olan yorgunluk protokolü çerçevesinde mekik koşusu koşmaya başlayacaklardır. Tükendikleri zaman koşuyu bırakacaklar ve hemen akabinde 1 kez yapılacak olan laktik asit ölçümü biter bitmez şut atışlarına geçeceklerdir. Sporcular kalenin dört köşesinde yer alan 50X50 cm boyutundaki hedeflere maksimal hızla dörder defa ve rastgele sıralamayla atış yapacaklar (toplam 16 atış), atışlar esnasında kolun ivmelenmesi ve topun hızı ölçülecektir.

Çalışma sonrasında sporcuların fizyolojik kapasitesi hakkında bilgi sahibi olunacak, ayrıca hentbol sporunda başarıya ulaşmada önemli rol oynayan şut isabetinin, atış hızının ve kolun ivmelenmesiyle ortaya çıkan hareket paterninin yorgunluktan ne kadar etkilendiği ve sporcunun atış tekniğini etkileyip etkilemediği belirlenmeye çalışılacaktır. Katılım sonunda, elde edilen sonuçlar takım antrenörüyle paylaşılacak olup bu bilgiler ışığında yapılacak olan antrenman programlarında sporcu ve antrenör lehine olumlu katkı sağlayacağı düşünülmektedir.

Çalışma süresince katılımcılar hiçbir surette potansiyel bir riske maruz kalmayacaklardır. Ayrıca çalışmaya katılım gönüllülük esasına dayalıdır ve katılımcı istediği zaman her hangi bir sebep göstermeksizin araştırmadan çekilebilir ve böyle bir durumda her hangi bir olumsuz sonuçla karşılaşmaz. Katılımcıların kişisel bilgileri ve çalışma esnasında çekilecek video görüntüleri özenle korunacak, araştırmacı dışında hiç kimse tarafından görülmeyecek ve çalışma dışında herhangi bir yerde kullanılmayacaktır.

Bu çalışmada katılımcı olunabilmesi için veli onayının yanı sıra, velisi olunan çocuğun kendi gönüllülüğü de bir ön şarttır.

İlginiz İçin Teşekkürlerimi Sunarım

Beyza ŞİMŞEK

Tel: (505) 886 66 03
e-posta: beyzasimsek@hotmail.com

Yukarıda açıklamasını okuduğum çalışmaya, oğlum ______________________'nin katılımına izin veriyorum.

Ebeveynin:
Adı, soyadı:
İmzası:
Tarih: ...../...../.....

Çocuğunuzun katılımı ya da haklarının korunmasına yönelik sorularınız varsa ya da çocuğunuz herhangi bir şekilde risk altında olabileceğine, strese maruz kalacağına inanıyorsanız Orta Doğu Teknik Üniversitesi Etik Kuruluna (312) 210-37 29 telefon numarasından ulaşabilirsiniz

APPENDIX C

HUMAN RESEARCH ETHIC FORM

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

DUMLUPINAR BULVARI 06800
ÇANKAYA ANKARA/TURKEY
T: +90 312 210 22 91
F: +90 312 210 79 59
ueam@metu.edu.tr
www.ueam.metu.edu.tr

Sayı: B.30.2.ODT.0.AH.00.00/126/119 – 1184

13 Nisan 2011

Gönderilen: Prof. Dr. Feza Korkusuz
Beden Eğitimi ve Spor Bölümü

Gönderen : Prof. Dr. Canan Özgen
IAK Başkan Yardımcısı

İlgi : Etik Onayı

" Hentbol Oyuncularının Kas Yorgunluğunun Şut İsabetine Etkisi " isimli araştırmanız "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

13/04/2011

Prof.Dr. Canan ÖZGEN
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı
ODTÜ 06531 ANKARA

APPENDIX D

TURKISH SUMMARY

HENTBOL OYUNCULARINDA KAS YORGUNLUĞUNUN
ATIŞ İSABETİNE ETKİSİ

1. GİRİŞ

Hentbol aralıklı yüksek şiddet ve vücut teması aynı zamanda aerobic ve anaerobic performans gerektiren koordine bir spor dalıdır (Chelly, 2011; Buchheit et.al., 2009; Buchheit and Leprette, 2009; Delamarche, 1987; Rannau, 2001). Hentbol içerisinde ağırlıklı olarak motor beceri, hızlı koşular, sıçrama, esneklik ve atış hızı barındırır ki bu da takım performansınıetkileyen önemli unsurlardır (Gorostiaga, 2006; Zapartidis et al., 2009).

Paslaşma ve yakalama hentbolde top kontrolü için en önemli bileşenlerdir. Atak başarısı, takımın topu bir oyuncudan diğerine hızlı ve isabetli bir şekilde iletebilme yeteneği ile ilintilidir. Isabetli paslar takım oyununun devamını sağlar ve defans oyuncusu üzerindeki baskıyı devam ettirerek her bir atak oyuncusuna skor yolunu açar (Clanton & Dwight, 1997).

2. YÖNTEM

Onaltı elit gençerkek hentbol oyuncusu çalışmaya gönüllü olarak katılmışlardır. Tüm katılımcılar ve onların ebeveynleri çalışma prosedürü, olası riskler ve rahatsızlıklar hakkında bilgilendirilmiş olup kendileri testler öncesinde gönüllü katılım formu ve ebeveyn onay formunu imzalamışlardır. Çalışma Orta Doğu Teknik Üniversitesi Etik Kurulu tarafından onaylanmıştır.

Table 2. Katılımcıların yaş, antrenman yaşı, boy uzunluğu, vücut ağırlığı ve vücut yağ yüzdelerine ilişkin betimleyici istatistik.

Değişken	Mean	Std.Dev
Yaş (yıl)	17.12	1.74
Antrenman yaşı (yıl)	9	1.41
Boy uzunluğu (cm)	185.26	7.17
Vücut ağırlığı (kg)	78.93	11.07
Yağ yüzdesi (%)	9.73	3.20
BKİ(kg/m2)	22.92	2.26

Not: BKİ= Beden kitle indeksi

Çalışma laboratuvar ve saha çalışması olmak üzere iki kısımdan oluşmuştur. Her katılımcı laboratuvar veya spor salonunu bir kez ziyaret etmiş olup ölçümler günün sabah saatlerinde gerçekleştirilmiştir. İlk gün5, ikinci gün 5 ve son gün 6 katılımcı testlere katılmış olup testler yaklaşık 30 dakika sürmüştür.Laboratuvar ve saha testleri arasında 48 saat ara verilmiştir. Tüm testler 6 gün içinde tamamlanmıştır.

Çalışma dizaynına göre katılımcılar once laboratuvar testlerine katılmışlardır. Laboratuvar testleri boy uzunluğu, vücut ağırlığı, vücut yağ yüzdesi, kalp atımı takibi, kan laktat konsantrasyonu ölçümü ve koşubandında koşu testi ve buradan elde edilen maksimal oksijen tüketimi (VO_2max) testlerini içermektedir. Katılımcıların boy uzunlukları ± 1mm hassasiyet derecesinde ölçüm yapabilen Holtain marka stadiometre, vücut ağırlığı ve vücut yağ yüzdeleri ise Tanita (TBF 300) marka vücut kompozisyon analizörü ile ölçülmüştür. Koşubandı testi için ise JAEGER marka (MasterScreen CPX; Viasys Healthcare GmbH) gaz analizör sistemi bağlı Jager marka (LE 200 CE) koşubandı kullanılmıştır. Gaz analizörü her kullanım günü sabahında kalibre edilmiştir.

Koşubandında 8 km/s ile ısınma koşusu başlamış ve 3 dakika sonrasında 9 km/s ile teste geçilmiştir. Bundan sonar her 3 dakikada bir 30 saniye dinlenme arası verilmiş ve bu sure zarfında sporcuların kulak memesinden 25µ kan alınarak YSI 1500 Sport marka laktik asit analizöründe kan laktat konsantrasyonu ölçülmüştür. Her 30 saniyelik dinlenme arası sonunda koşubandının hızı 1km/s artırılmıştır (Demarie, 2000; Midgley, 2007). Yine her 3 dakikalık sürenin başlangıç ve sonunda Polar marka nabız ölçer saat ile kalp atım hızı takibi yapılmıştır. Test, katılımcı tükendiğini ifade edip kendi idteğiyle bıraktığı zaman, maksimal kalp atım hızının %90'ına ulaşıldığı zaman ve kan laktat değerinin 8mmol ve üzerine çıktığı zaman sonlandırılmıştır.

Koşubandından elde edilmiş olan katılımcıların VO_2max değerlerinin %75'ine denk gelen koşu hızı hesaplanarak aralıklı fitness mekik koşusu testi (30-15_{IFT}) için başlangıç hızı, dolayısıyla bireysel yorgunluk protokolleri oluşturulmuştur.

Saha testlerinde ise öncelikle katılımcılara hedefsiz duvara maksimal hızda 5 adet şut attırılıp, bu şutların en yüksek ve en düşük olanı dışarıda tutularak ortadaki 3 hız değerinin ortalaması optimal atış hızı olarak belirlenmiştir. Katılımcılar bundan sonraki aşamada yer alan hedefe şut testinde, kendileri için belirlenen atış hızının altında kalmayacak şekilde atış yapmışlardır. Kalenin dört köşesine 50X50cm boyutlarında, profil demirden ve içi boş olacak şekilde hedefler yerleştirilmiştir. Her hedefin arkasına ise 15X15cm boyutunda yeşil LED ışıklarla döşenmiş tabelalar yerleştirilmiştir. Bu ışıklı tabelalar elektreikli bir kutuya kablolarla bağlanmış olup, araştırmacılar tarafından önceden belirlenmiş olan rastgele sıralama ile 3 saniye aralıklarla görsel sinyal verilmş ve katılımcının ışığı görür görmez ışığın yandığı hedefe doğru teknik ve maksimal hızla atış yapması istenmiştir. Atışlar esnasında katılımcıların el bileklerine üç eksenli Biopac (SS27L, ±50g range) marka ivme ölçer yerleştirilerek sporcunun X, Y ve Z eksenlerinde bilek ivmeleri ölçülmüştür. Ayrıca tüm atışlarda katılımcının arkasında ve kol hizasında yer alacak şekilde Sports Radar Gun (SR 3600) marka hız ölçer cihaz ile topun hızı kaydedilmiştir.

Yorgunluk protokolü öncesinde kalenin 4 köşesindeki hedeflere 4'er tane olmak üzere rastgele şekilde ve toplam 16 adet atış yaptırılmıştır. Akabinde katılımcının kulak memesinden alınan 25µ kandan laktik asit ölçümü yapılmış ve başlangış laktat olarak kaydedilmiştir. Sonrasında katılımcılar $30\text{-}15_{IFT}$ testine başlamışlardır. $30\text{-}15_{IFT}$ bir çeşit mekik koşusu olup hentbolün doğasına uygun olarak 40metrelik sahada uygulanmaktadır. Test 30 saniyelik yüklenme ve 15 saniyelik dinlenme periyotlarını içermektedir. Her yüklenme evresinde hız 0.5 km/s artırılıp sporcu tükeninceye, kalp atım hızı maksimal kalp atım hızının %90'I veya üzerine çıkıncaya veya ses sinyali geldiğinde sahanın başında, ortasında ve sonunda bulunan 3 metrelik alanları ardışık bir şekilde 3 kez yakalayamayana kadar devam etmiştir. (Buchheit et.al., 2009; 2010). Test boyunca katılımcının her 45 saniyede kalp atım hızı kaydedilmiştir.

Yorgunluk protokolü sonrasında katılımcının kan laktat ölçümü en kısa zamanda gerçekleştirilip yorgunlup öncesinde yapılan hedefe atış (her hedefe 4 atış; toplam 16 atış) testi uygulanmıştır. Test esnasında el bileği ivmesi ve topun hızı kaydedilmiştir.

3. BULGULAR

Tablo 4. Hentbol oyuncularının yorgunluk öncesi ve sonrası isabetli ve isabetsiz atış toplam puanları farkı için ilişkili örneklemler için t-testi sonuçları.

Ölçüm	Mean	Sd	T	P
İsabetli Pre-test	5.31	2.08	-.83	.415
İsabetli Post-test	5.87	2.06		
İsabetsiz Pre-test	10.68	2.08	.76	.459
İsabetsiz Post-test	10.18	1.97		

Tablo 4 incelendiğinde hentbolcuların yorgunluk protokolü öncesi ve sonrasındaki isabetli ve isabetsiz atış puanları değerlerinde istatistiksel olarak anlamlı bir farklılık görülmemektedir ($p>0,05$). Bu bulguya göre isabetli ve isabetsiz atış performansı yorgunluktan etkilenmemektedir.

Hentbolcuların yorgunluk protokolü öncesi ve sonrasındaki hedefe atış esnasındaki kol ivmelerin x, y ve z eksenlerine ait değerleri arasındaki farklılık için uygulanan ilişkili örneklemler için T-testi sonuçlarına gore hentbolcuların yorgunluk protokolü öncesi ve sonrasındaki hedefe atış esnasındaki kol ivmelerin x, y ve z eksenlerine ait değerlerine göre; Y eksenindeki isabetsiz atış değerleri istatistiksel olarak anlamlı bir farklılık göstermektedir [$t(15)= -2,259$, $p<0,05$]. Bu bulguya göre hentbolculara uygulanan yorgunluk protokolü hedefe isabet değerlerinde Y eksenindeki ivmesel hareketi etkilediği görülmektedir. Diğer eksenlerdeki isabetli ve isabetsiz atışların yorgunluk protokolünden etkilenmediği görülmektedir ($p>0,05$).

Hentbolcuların hedefe isabet puanların yordanmasına ilişkin regresyon analizi sonuçlarına göre hentbolcuların yorgunluk protokolü öncesindeki atış yörünge benzerliği, topun hızı ve kolun x, y ve z eksenine ait ivme değişkenleri birlikte, hedefe isabet değerleri ile yüksek düzeyde ve anlamlı bir ilişki görülmektedir (R=,789, R2=,622). Adı geçen değişkenler birlikte toplam varyansın % 62'ini açıklamaktadır.

Standardize edilmiş regresyon katsayısına göre (β) göre, yordayıcı değişkenlerin hedefe isabet puanları üzerindeki göreli önem sırası; x eksenindeki değişim, atış benzerliği, x eksenindeki değişim, topun hızı, reaksiyon zamanı, z eksenindeki değişim ve y eksenindeki değişim şeklindedir. Regresyon katsayılarının anlamlılığına ilişkin t-testi sonuçları incelendiğinde ise, sadece atış benzerliği değişkeninin hedefe isabet üzerinde anlamlı bir etkiye sahiptir. Diğer değişkenler hedefe isabet üzerinde önemli bir etkiye sahip değildir.

Hentbolcuların hedefe isabetsiz puanların yordanmasına ilişkin regresyon analizi sonuçlarına göre hentbolcuların yorgunluk protokolü öncesindeki atış yörünge benzerliği, topun hızı ve kolun x, y ve z eksenine ait ivme değişkenleri birlikte, hedefe isabetsiz şut değerleri ile orta düzeyde ve anlamlı bir ilişki görülmektedir (R=,803, R2=,645). Adı geçen değişkenler birlikte toplam varyansın % 65'ini açıklamaktadır.

Standardize edilmiş regresyon katsayısına göre (β) göre, yordayıcı değişkenlerin hedefe isabetsiz puanları üzerindeki göreli önem sırası;

topun hızı, atış benzerliği, x eksenindeki değişim, z eksenindeki değişim ve y eksenindeki değişim şeklindedir. Regresyon katsayılarının anlamlılığına ilişkin t-testi sonuçları incelendiğinde ise topun hızı ve atış benzerliği değişkeninin hedefe isabetsizlik üzerinde anlamlı bir etkiye sahiptir. Diğer değişkenler hedefe isabetsizlik üzerinde önemli bir etkiye sahip değildir.

Hentbolcuların hedefe isabet puanların yordanmasına ilişkin regresyon analizi sonuçlarına göre hentbolcuların yorgunluk protokolü öncesindeki atış yörünge benzerliği, reaksiyon zamanı, topun hızı ve kolun x, y ve z eksenine ait ivme değişkenleri birlikte, hedefe isabet değerleri ile yüksek düzeyde ve anlamlı bir ilişki görülmektedir (R=,798, R2=,637). Adı geçen değişkenler birlikte toplam varyansın % 64'ünü açıklamaktadır.

Standardize edilmiş regresyon katsayısına göre (β) göre, yordayıcı değişkenlerin hedefe isabet puanları üzerindeki göreli önem sırası; topun hızı, atış benzerliği, reaksiyon zamanı, y eksenindeki değişim, x eksenindeki değişim ve z eksenindeki değişim şeklindedir. Regresyon katsayılarının anlamlılığına ilişkin t-testi sonuçları incelendiğinde ise, hiçbir değişken hedefe isabet üzerinde önemli bir etkiye sahip değildir.

Hentbolcuların hedefe isabetsiz puanların yordanmasına ilişkin regresyon analizi sonuçlarına göre hentbolcuların yorgunluk protokolü sonrasında atış yörünge benzerliği, topun hızı ve kolun x, y ve z eksenine ait ivme değişkenleri birlikte, hedefe isabetsiz şut değerleri ile orta düzeyde ve anlamlı bir ilişki görülmektedir (R=,465, R2=,217). Adı geçen değişkenler birlikte toplam varyansın % 22'sini açıklamaktadır.

Standardize edilmiş regresyon katsayısına göre (β) göre, yordayıcı değişkenlerin hedefe isabet puanları üzerindeki göreli önem sırası; y eksenindeki değişim, x eksenindeki değişim, atış benzerliği, z eksenindeki değişim ve topun hızı şeklindedir. Regresyon katsayılarının anlamlılığına ilişkin t-testi sonuçları incelendiğinde ise, hiçbir değişken hedefe isabet üzerinde önemli bir etkiye sahip değildir.

4. SONUÇ VE ÖNERİLER

Bu çalışma, yorgunluğun şut isabetine etkisini incelemeyi amaçlamıştır. Çalışma sonucunda ana sonuç olarak yorgunluk öncesi ve sonrası şut isabet oranları arasında farklılık bulunamamıştır. Bir digger deyişle yorgunluğun şut isabetini etkilemediği görülmüştür. Bu durumun, testin yorgunluk öncesi denemesinde katılımcılar tarafından öğrenilmiş olmasının etkisi olabileceği düşünülmektedir. Ayrıca sporcular genç olmalarına ragmen elit seviyede sporcular olup haftada 10 antrenman yapmaları ve her antrenman süresince onlarca şut atmalarının yorulsalar bile atış isabetine çok etki etmesine imkan tanımadığı, özellikle atış kolu kasları yorulmadığı sürece sonuca çok fazla etki etmeyeceği düşünülmektedir. Bu sebeple tüm vücut yorgunluk protokolü yerine veya yanısıra local yorgunluk protokolü uygulanırsa farklı sonuçlar elde edilebileceği tahmin edilmektedir.

Çalışmanın diger bulguları ise, şut atış benzerliği, topun hızı, tepki süresi, el bileğinin X, Y ve Z eksenlerindeki ivmelenmesinin şut isabetini etkileyen faktörler olarak birbirleriyle yüksek korelasyon içinde oldukları görülmüştür. Özellikle şut atış benzerliğinin isabetli atışlarda, topun hızının da isabetsiz atışlarda etkili olduğu görülmüştür. Diğer taraftan el bileği ivmelenmesinde yorgunluk öncesi ve sonrasında fark tespit edilmiş olup yorgunluk öncesinde sağdan sola harekette, yorgunluk sonrasında ise arkadan öne harekette önemli artış olduğu saptanmıştır. Bu durmun sporcunun yorgunluğun etkilerini azaltmak adına hareketi daha kolay hale getirebilmek için tercih ettiği düşünülmektedir.

Araştırmacılara önerim, omuz kaslarını yoracak biçimde tasarlanmış bir local yorgunluk protokolünün uygulanmasının farklı sonuçlar elde edilebileceği yönünde olup, yorgunluk protokolünün farklı şekilde dizayn edilmesidir.

APPENDIX E

DISSERTATION PERMISSON FORM

METU LIBRARY

TEZ FOTOKOPİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü [ ]

Sosyal Bilimler Enstitüsü [x]

Uygulamalı Matematik Enstitüsü [ ]

Enformatik Enstitüsü [ ]

Deniz Bilimleri Enstitüsü [ ]

YAZARIN

Soyadı : Şimşek
Adı : Beyza
Bölümü :Beden Eğitimi ve Spor

TEZİN ADI (İngilizce) : Effects of muscle fatigue on shooting accuracy in handball players

TEZİN TÜRÜ : Yüksek Lisans [ ] Doktora [x]

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. [x]

2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullancılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [ ]

3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [ ]

Yazarın imzası Tarih

APPENDIX F

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name	:	Şimşek, Beyza
Nationality	:	Turkish (TC)
Date and Place of Birth	:	01.05.1974, İzmir
Marital status	:	Married
Phone	:	+90 318 357 42 42
Fax	:	+90 318 357 38 63
E-mail	:	bsimsek@kku.edu.tr

EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	Ankara University / PES	2002
BS	METU / PES	1999

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2005-Present	Kırıkkale University	Instructor
2001-2002	TED Ankara Collage	PE Teacher

COURSES TAUGHT: Coaching Volleyball, Sports Injury and Rehabilitation

FOREIGN LANGUAGE: English

PUBLICATIONS / PRESENTATIONS

1. Deliceoğlu, G., Şimşek, B. (2006). Futbolcuların anaerobic eşikteki kalp atım hızı ve toparlanma düzeyleri arasındaki ilişki. IX. International Sports Sciences Congress, 03-05 November, Muğla, Turkey.

2. Arpınar, P., Şimşek, B., Sezgin, Ö.C., Birlik, G., Korkusuz, F. (2005). Correlation between mechanical vibration analysis and dual energy X-ray absorptiometry (DXA) in the measurement of in vivo human tibial bone strength. (2005). Technology and Health Care 13(2): 107-13.

3. Ergen, E., Şimşek, B. (2004). Shoulder strengthening exercises for injury prevention in archery. Chapter in Sports Medicine and Science in Archery. Published by International Archery Federation, Medical Committee.

4. Avşar, P.A., Soylu, A.R., Ertan, H., Şimşek, B., Korkusuz, F.(2004). Back muscle fatigue in submaximal ergometer rowing: An EMG study. The 10th ICHPER-SD Europe Congress and The TSSA 8th International Sports Sciences Congress, 17 – 20 November, Antalya/Turkey.

5. Şimşek, B. Tuncel, F. Ertan, H. Göktepe, S. (2002). The Evaluation of Physical Fitness Parameters at Different League Categories in Female Volleyball Players. VII. International Sports Sciences Congress, 27-29 October Antalya, Turkey.

6. Şimşek, B., Tuncel, F., Ertan, H., Göktepe, S. (2002). The Evaluation of Jumping Height and Knee Muscle Strength among Female Volleyball Players. VII. International Sports Sciences Congress, 27-29 October. Antalya, Turkey.