T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
MASTER'S PROGRAM IN SPORTS PHYSIOTHERAPY

THE EFFECT OF SIX-WEEKLY PLYOMETRIC EXERCISES ON JUMPING, SPRINTING, THROWING AND DYNAMIC BALANCE CAPACITIES ON WOMEN VOLLEYBALL PLAYERS

Master Thesis

Seda Nur ÇİMEN,PT

İSTANBUL

2019

T.C.
YEDİTEPE UNIVERSITY
INSTITUTE OF HEALTH SCIENCES
MASTER'S PROGRAM IN SPORTS PHYSIOTHERAPY

THE EFFECT OF SIX-WEEKLY PLYOMETRIC EXERCISES ON JUMPING, SPRINTING, THROWING AND DYNAMIC BALANCE CAPACITIES ON WOMEN VOLLEYBALL PLAYERS

Master Thesis

Seda Nur ÇİMEN, PT

ADVISER

PROF. Dr. FERYAL SUBASI, PT

İSTANBUL

2019

TEZ ONAYI FORMU

Kurum : Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü

Program : Spor Fizyoterapisi

Tez Başlığı : The Effect of Six-Weekly Plyometric Exercises on Women Volleyball Players on Jumping, Throwing, Sprinting and Dynamic Balance Capacities

Tez Sahibi : Seda Nur GİMENİ

Sınav Tarihi : 09.07.2019

Bu çalışma jurimiz tarafından kapsam ve kalite yönünden Yüksek Lisans Tezi olarak kabul edilmiştir.

	Unvanı, Adı-Soyadı (Kurumu)	İmza
Jüri Başkanı:	Dr. Öğr. Üyesi Gigdem Yazıcı Mutlu	
Tez danışmanı:	Prof. Dr. Feryal SUBAŞI	
Üye:	Dr. Öğr. Üyesi Gigdem YAZICI MUTLU	
Üye:	Dr. Öğr. Üyesi Secil ÖZKURT	
Üye:		

ONAY

Bu tez Yeditepe Üniversitesi Lisansüstü Eğitim-Öğretim ve Sınav Yönetmeliğinin ilgili maddeleri uyarınca yukarıdaki jüri tarafından uygun görülmüş ve Enstitü Yönetim Kurulu'nun 16/07/2019 tarih ve 2019/12-07 sayılı kararı ile onaylanmıştır.

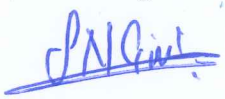
Prof. Dr. Bayram YILMAZ
Sağlık Bilimleri Enstitüsü Müdürü

DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which has been accepted for the award of any other degree except where due acknowledgment has been made in the text.

Seda Nur Çimen

Signature



DEDICATION

I would like to dedicate my thesis to my beloved parents Yaşar and Muharrem ÇİMEN and my lovely sister Merve ÇİMEN and I also thank everyone who contributed on me.

ACKNOWLEDGEMENT

I would like to express deepest appreciation to Professor Feryal SUBAŞI who continually provide us all support and guidance which makes this project possible.

My dear friend and colleague Pt. Ayça YAĞCIOĞLU has been with me at every stage of my thesis and I sincerely thank her for her help and support.

I would like to thank Sarıyer Municipality volleyball athletes for their participation and Ceren GÖKKAYA for her support in shooting exercise and evaluation photographs and my colleagues Mustafa DELİOĞLU and Ali KAYAOĞLU.

Finally, I would like to thank my dear friend Betül DUMAN , her support, motivation and strong friendship and my dear family for giving me strength and supporting me in every period of my life.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

LIST OF SYMBOLS/ABBREVIATIONS

GTO	Golgi Tendon Organ
SM	Starting Momentum
L	Load
A	Amortization
D	Discharge
FM	Final Momentum
SD	Standart deviation
N	Case number
G1	First Group
G2	Second Group
BMI	Body Mass Index

ABSTRACT

Çimen, S.N. The effect of six-weekly plyometric exercises on women volleyball players on jumping, sprinting, throwing and dynamic balance capacities. Yeditepe University Institute of Health Sciences Sport Phsiotherapy Program. Master thesis. Istanbul (2019).

The aim of this study was to investigate the effect of six-week plyometri exercises on running, jumping, throwing and dynamic balance capacities in female volleyball players. Thirty female volleyball players were included in the study. The subjects were divided into two groups as the study group (n=15) with a mean age of 16.53±1.45 years and the control group (n=15) with a mean age of 16.33±1.49 years. The athletes in the first group were taken to the Plyometric exercise training program (2 days/week) in addition to the classical training programs. The second group participated the classical training program for six weeks. Both groups were evaluated with the same methods before and after a six-week pliometric exercise training program. The subjects were assesed by physical measurement, vertical jump test, 20 m sprinting test, Y balance test and ball throw test. There was a statistically significant difference in right anterior and posteromedial and left anterior, posteromedial and posterolateral values of Y balance test , vertical balance and ball throwing values before and after training in the study group in which pliometric exercise program was given ($p < 0.05$). There was no significant difference at 20 m sprinting and right posterolateral value of Y balance test ($p > 0.05$). According to the evaluation results between groups; While vertical jump and ball throwing difference values increased ($p < 0,05$), no significant difference was found in the Y balance test left anterior, posteromedial and posterolateral differences and 20 m sprinting test ($p > 0.05$). As a result, it is considered that plyometric training program could be especially useful to include professional athletes's in training programs since plyometric exercise training combine with training program leads the significant improvements in vertical jump, the ball throwing and balance parameters.

Key Words: Plyometric exercise, Volleyball, Women Player

ÖZET

Çimen, S.N. Kadın voleybol oyuncularda altı haftalık pliometrik egzersizlerin koşu, sıçrama, fırlatma ve dinamik denge kapasiteleri üzerine etkisi. Yeditepe Üniversitesi Sağlık Bilimleri Enstitüsü Spor Fizyoterapisi Programı. Yüksek Lisans Tezi. İstanbul (2019).

Bu çalışmanın amacı, kadın voleybol oyuncularda altı haftalık pliometrik egzersizlerin koşu, sıçrama, fırlatma ve dinamik denge kapasiteleri üzerine etkisini araştırmaktır. Çalışmaya 30 kadın voleybol oyuncusu dahil edildi. Olgular yaş ortalaması 16,53±1,45 yıl olan birinci grup (G1) (n=15) ve yaş ortalaması 16,33±1,49 yıl olan ikinci grup (G2) (n=15) olmak üzere iki gruba ayrıldı. Birinci gruba klasik voleybol antrenmanı ile birlikte altı hafta süresince (2 gün/ hafta) pliometrik egzersiz eğitim programı uygulandı. İkinci grup klasik antrenman programına katıldı. Her iki grup , altı haftalık pliometrik egzersiz eğitim programı öncesi ve sonrasında aynı yöntemlerle değerlendirildi. Bireyler fiziksel özellikleri, dikey sıçrama testi, 20 m koşu testi, Y denge testi ve top fırlatma testi ile değerlendirildi. Pliometrik egzersiz programının verildiği çalışma grubunda eğitim öncesi ve sonrası dikey sıçrama ve top fırlatma değerlerinde ve Y denge testinin sağ anterior ve posteromedial ile sol anterior, posteromedial ve posterolateral değerlerinde istatiksel olarak anlamlı fark vardır ($p<0,05$). 20 m koşu değerinde ve Y denge testinin sağ posterolateral değerinde anlamlı bir fark yoktur ($p>0,05$). Gruplar arası değerlendirme sonuçlarına göre; dikey sıçrama ve top fırlatma fark değerinde artış gösterirken ($p<0,05$), gruplar arası 20 m koşu ve Y denge testinde sol anterior, posteromedial ve posterolateral fark sonuçlarında anlamlı bir fark yoktur ($p>0.05$). Sonuç olarak, pliometrik egzersiz programının, profesyonel sporcuların antrenman programlarına dahil edilmesinde özellikle faydalı olabileceği düşünülmektedir, çünkü pliometrik egzersiz eğitimi, antrenman programı ile birleştiğinde dikey sıçrama, top fırlatma ve denge parametrelerinde önemli gelişmelere yol açmaktadır.

Anahtar Kelimeler: Pliometrik egzersiz,voleybol, kadın sporcu

1. INTRODUCTION

Volleyball is an enjoyable game which is played in accordance with certain rules and has become very popular today for both performance sports and recreation purposes (1). Volleyball, appealing to a wide audience in our country as well as all over the world, is a team sport that involves continuous movements, complex movements and requires versatile skills and performance (1,2).

The aim of the volleyball game is to send the ball to the opponent area by passing the ball over the net in accordance with the rules for each team and to prevent the ball from coming into contact with the ground in its area (3). The game, which starts with the service shot, continues until the ball touches the playing field of one of the teams, until one of the teams makes a mistake or the ball goes out of the playing area (4).

A volleyball game can be defined as an integrated game with six main skills. These skills are service, bump, overhand pass, spike, block and dive-dive & roll (5). In order to develop these skills, all segments move in the most appropriate position and the kinetic movement pattern is generated by the kinetic energy provided by many muscles working in coordination. In overhead throwing techniques such as bumping, service and pass, arm movements are divided into phases and the ball is hit by eccentric external rotation and concentric internal rotation of the shoulder (6,7). Continuous repetitive jumps associated with spike, block, and spike service are biomechanically in three forms; squat jump, countermovement jump, drop jump and characterized by the same muscle activation pattern (5,8).

Volleyball sports demand high performance efficiency from players together with the sprinting of explosive strength, effective and sudden movements against the ball coming from the opponent, repeated vertical jumps for attack and block, and the ability to adapt to the tempo of the match for five sets (9). In order to be successful in the game, the volleyball player must possess skills such as strength, endurance, quickness, flexibility and speed. A high level of balance, coordination and skill is required for the synchronized and fluent display of basic techniques (10).

Plyometric is a Latin word, which means measurable acceleration (11,12). Plyometric is a way to increase sporting performance by training with skipping, jump and throw methods for strength or explosion. Plyometric exercises, by using the tension-contraction cycle, aim to increase the explosive reaction of the athlete with

strong concentric contraction by stimulating the tension reflex after rapid eccentric contraction (12). The faster the muscle is stretched, the more power and strength it produces (13).

Vertical jump and spike, which is an indicator of explosive strength, is an important feature that should be present in volleyball players. It has been claimed that plyometric training increases the vertical jump ability and explosive strength performance. Plyometric exercise is also an effective method to increase balance, strength, joint awareness and condition in athletes (14).

In the literature, in a study conducted on 14-year-old female volleyball players, it was reported that the effect of eitght-weekly plyometric exercises on jump and throwing capacity improved (15). An increase was found in a study investigating the effects of 12-week plyometric exercises on 10 elite female volleyball players on muscle strength, ejection and countermovement jump performance (16). Two studies conducted on kinematic parameters of young female volleyball players indicated that significant improvements in generic performance and vertical jump of 5 and 6 week plyometric exercises (17,18).

As a result of the literature review, it was seen that plyometric exercises result with physical improvements in athletes. Therefore, the purpose of this study was to search the effect of six-week plyometric exercises on running, jumping, throwing and dynamic balance capacities in female volleyball players.

Hypotheses of the study;

1. H0: Plyometric exercises have no effect on running, jumping, throwing and dynamic balance capacities of female volleyball players.

2. H1: Plyometric exercises have an effect on running, jumping, throwing and dynamic balance capacities of female volleyball players.

2. GENERAL INFORMATION

2.1.Volleyball and Physiology

Volleyball was defined by William Morgan in 1895 as an entertainment game called “Minotte”. Volleyball, which has been through many changes until today, is a sport that requires basic motoric features and intelligence. In this sport, the goal is to score points by making the ball fall on the opponent's field without dropping the ball in own field and allow the opponent team players to make mistakes (19).

Volleyball is played on an 18x9 m playground divided in two by a net, in official competitions on the grounds where the floor of the hall is covered with wood or synthetic material. The leather covered volleyball ball has a diameter of 16.5 cm and a weight of 196-280 grams. The height of the net is 2.24 meters for women and 2.43 meters for men (20,21) (Figure 2.1).

A volleyball team includes 6 players with team positions defined as setter, setter cross, spiker, mid-player and libero. Each of these positions belongs to the game of volleyball performs six main skills; service, bump, overhand pass, spike, block and dive-dive and roll during the game (5).

The physiological character of volleyball is that the loading phase and the resting phase are intertwined with each other in a short term of time and maximum power is used with varying duration and movement intensity in the 9 meter long playground, players jump for attack and block, jump in different directions or up to 10 meters specific offensive and defensive performances such as running (12,22,23).

Figure 2.1. Volleyball (22)

2.1.1. Basic Skills Techniques and Biomechanics of Volleyball

2.1.1.1.Service

In volleyball, service is defined as the hit that starts the game. In volleyball, it is commonly seen in two types; tennis (flying) service and spike service (24).

In the tennis service, the player stands with his upper body facing the direction in which the ball will be thrown. The ball is held in the non-dominant or left hand while the non-dominant or left foot is positioned in the front, allowing trunk rotation. With the trunk extension, the dominant arm is raised backwards and the ball is thrown into the air. The ball is hit by taking a small step (20) (Figure 2.2).

In the spike service, the ball is held in the dominant hand and stepping up with the dominant foot starts stepping forward and the ball is rapidly hit in step 4 with the palmar face of the hand. Arm swing determines the way the ball is met and the speed (25) (Figure 2.3).

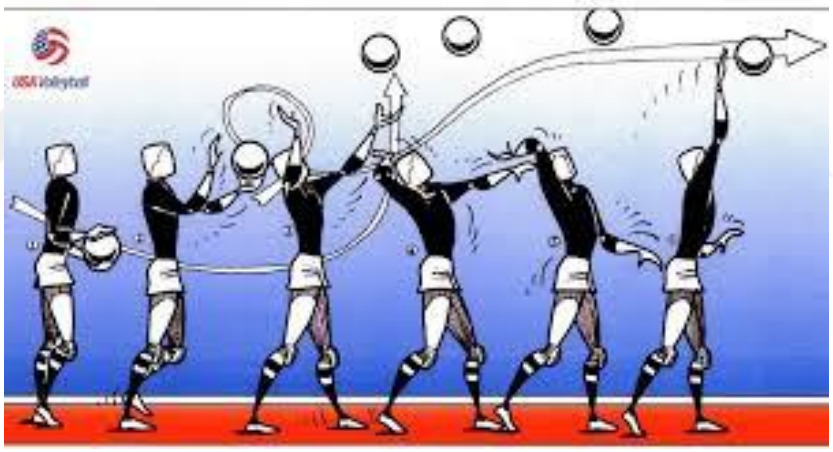


Figure 2.2. Tennis Service (26)

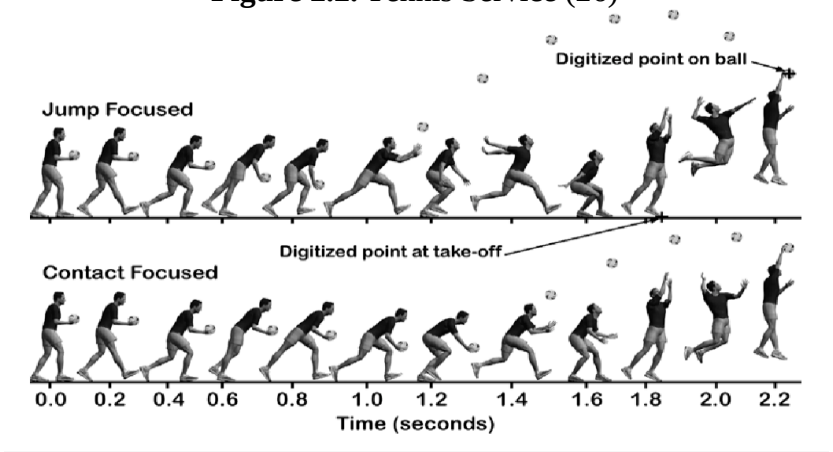


Figure 2.3. Spike Service (27)

2.1.1.2.Bump

It is generally used in the service reception position in the game. In addition to meeting the service, it is the most commonly used technique in the defensive position against the opponent's attacks in the back area. In the preliminary preparation phase of the bump, the shoulders are protracted while the hip is positioned at back and back at a 45 degree angle from the hip, and the arms are joined away from the body in contact with the ball and the forearm is supinated so that the inner parts meet the ball. In this position, the center of gravity is transferred to the front and the foot that weight is to be transferred and the side that arms are extended vary according to the direction of arrival of the ball. The movement and positioning of the step before the player contact with the ball is important in terms of ensuring stroke quality and balance (25) (Figure 2.4).

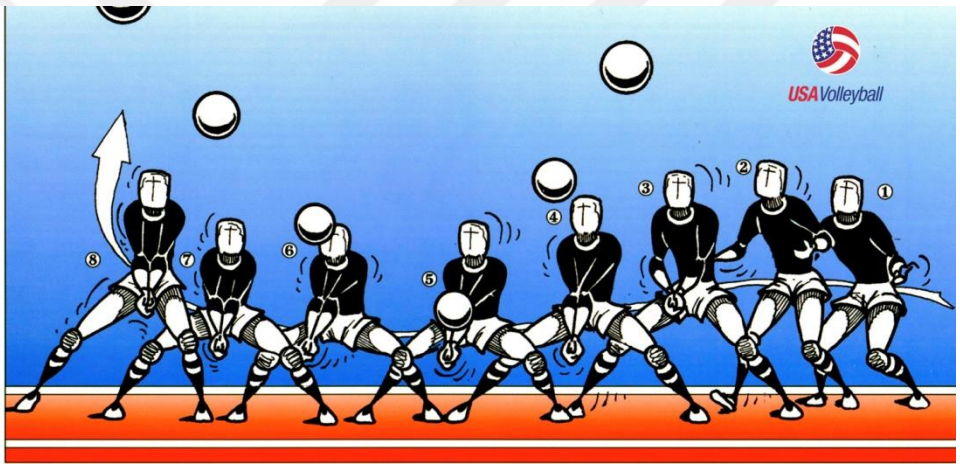


Figure 2.4. Bump (26)

2.1.1.3.Finger pass

Overhand pass is used to set a set by the setter who usually uses the second hit after the first meet to the ball passing the net with the opponent's service kick (20).

A good setter can pass balls at various heights and tempo (29). For forward passes, the foot position is positioned side by side or one foot in front. In the position where a foot is put forward, the fingertips are pointing towards the target and the weight is in the front foot. The knees are semi flexed and the back is straight. Elbows are at least 90 degrees of flexion, hands are at the forehead level and 15-30 cm in front of the head. The last stage is entered after meeting the ball while the thumb, index finger and middle finger are in abduction. The ankles, knees, elbows and wrists are activated in order to transfer energy to the direction of the ball, the body is straightened and the ball

is pushed by the ulnar deviation movement in the wrist (Figure 2.5) There is an energy transfer that starts from the ankle in backward pass, single hand pass and jumping pass (6,28).

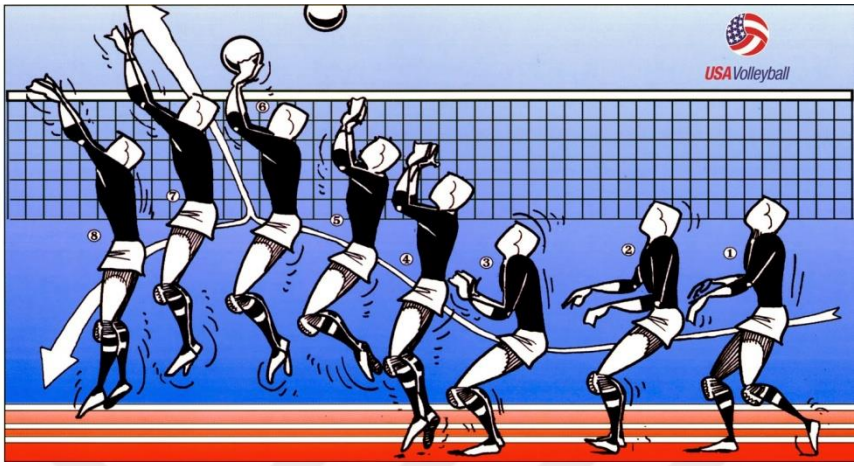


Figure 2.5. Finger Pas (26)

2.1.1.4.Spike

It is a hit technique of attack (20). The spike technique is a complex technique. Basically, there are preparation step, approach run, discontinuation of the contact with the ground with the last step, elevation, backward extension, flexing forward, ball contact and falling down stage (19).

It has a complex structure that requires coordination and starts with stepping. Right-handed kickers gain momentum when stepping right-left-right-left. In the last two steps, the distances approach each other and two foot are used when jumping. In step 3, the arms are thrown back and the body moves forward. With step 4, the arms are lifted up to about 30cm above the ball while jumping. The right arm elbow is pulled back by bending and is hit rapidly when the moment of contact with the ball comes (30) (Figure 2.6). The well-timed arm swings allow the hips to pass in front of the shoulders. This allows the player to hit the ball in an upright position. The criterias important in this technique are intervening of the arrival speed in the jump strength, the function of the hip in the jump, the use of the arm as a whip, and most importantly timing (20,25).

Figure 2.6. Spike (26)

2.1.1.5.Block

The block technique can be thought of as the first stage of defense and is mainly applied to stop the opponent attacker. Initially made with one person, it is done with the participation of two and three players according to the strength of the opponent spiker. In the waiting for the block in front of the net, the feet are open at the shoulder level and the palmar surfaces of the hands are facing the net. With side-stepping towards the attacker, the hip goes back to the mini-squat position and a vertical jump is made to meet the ball (25) (Figure 2.7). The arms extend towards the ball and the hands are brought closer to each other to prevent the ball from passing (19,20).

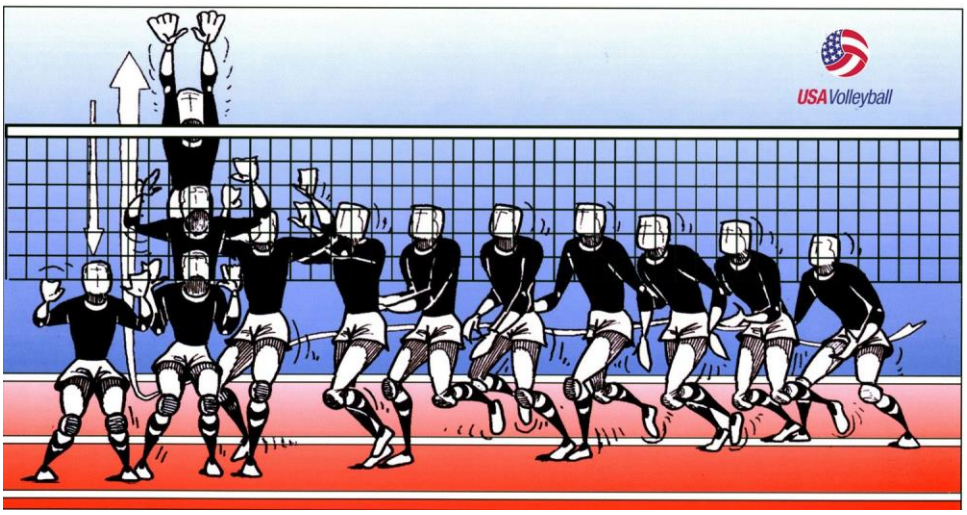


Figure 2.7. Block (26)

2.1.1.6.Dive-dive & Roll

Dive-dive & Roll technique is used to rescue the balls that are far away from the player in which the bump technique cannot be applied (19). The whole body weight is transferred to the foot positioned in the direction of the ball and the arm is extended towards the bottom of the ball (25) (Figure 2.8). The ball is lifted up and reached the upright position With the techniques such as creeping on the abdomen and rolling down (20,30).

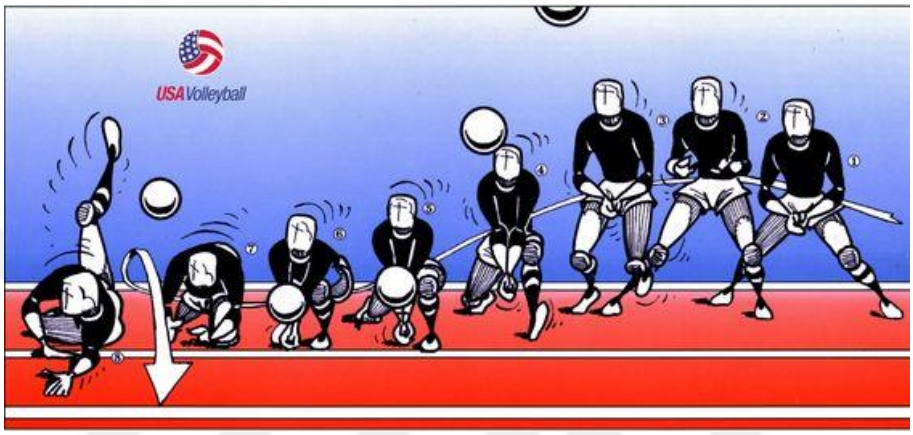


Figure 2.8. The dive-dive & roll (26)

In order to move all segments in the most appropriate position, many muscles work in coordination. In overhead throwing movements such as striking, service and pass, arm movements are divided into phases and the kinetic energy required for the formation of each movement pattern is provided by the muscles' ability to contract (6,25) (Figure 2.9).

In general, the throwing movement is divided into six phases. Although these six phases are continuous, they are often separated by strengths and changes in muscle activity during the throwing cycle (7,31) (Figure 2.10).

1st Phase (wind-up) Elevation; this is the preparation phase with minimal muscle activity. At the end of this phase, the shoulder is in slight abduction and internal rotation (24,32).

2nd Phase ("early cocking" or "stride"); this phase, which has minimal loading, ends with 90 degrees abduction and 15 degrees horizontal abduction of the shoulder. First, the deltoid muscle, then infraspinatus, teres minor muscle and supraspinatus (rotator cuff) are involved in the movement (24,33).

3rd Phase ("late cocking"); It continues until the shoulder reaches maximum external rotation. The humeral head is stabilized by retraction of the scapula and the elbow is flexed. In the middle of this phase, while the supraspinatus, infraspinatus and reverse minor activity reach their maximum and deltoid muscle activity decreases. The spikers combine this phase of movement with trunk rotation and lumbar extension (30). In the last section of this phase, the subscapularis muscle is fired by trunk rotation and the pectoralis major, latissimus dorsi and serratus anterior muscle are contracted eccentricly. Biceps muscle activity is moderate (24,33).

4th Phase (acceleration); This phase actually begins with trunk derotation and lumbar flexion (30). The shoulder goes to internal rotation when in abduction (approximately 140-170 °). In this phase, the stabilization of the humeral head is achieved by scapula protraction and concentric contraction of the anterior group muscles and eccentric contraction of the posterior muscles of the shoulder. At the beginning of this phase, the triceps muscle is active and at the end of this phase latissimus dorsi, pectoralis major and serratus are anterior muscles are active (24,34).

5. Phase (deceleration): the most risky phase of the overhead ejection movement, which is the opposite of the movement made in the first three phases. This phase starts with hitting of the ball and ends with 100 ° abduction and 35 ° horizontal adduction of the shoulder. The eccentric contraction of the muscles on the posterior shoulder terminates the ejection movement (34).

6.Phase (-follow-through "): It is the rebalance phase and the body is moved forward until the ejection movement stops. Shoulder abduction is fixed at 100 °, horizantal adduction increases from 30 ° to 60 ° (24).

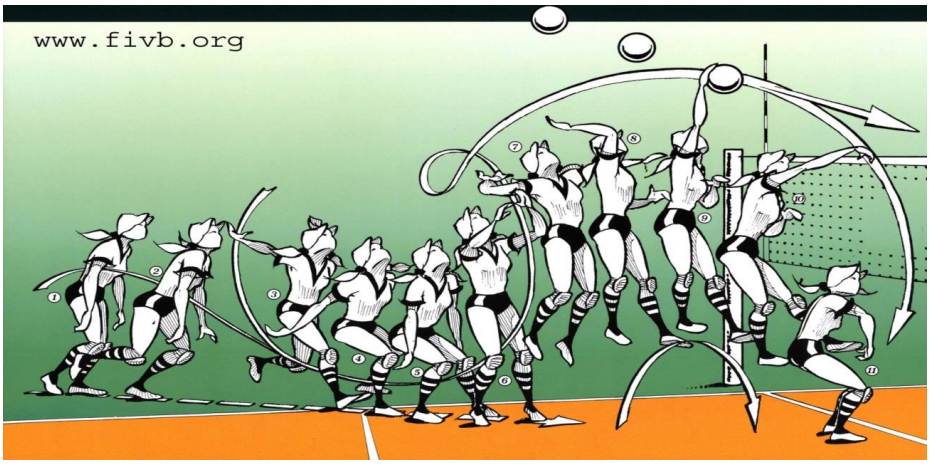


Figure 2.9. Spike movement in volleyball (26)

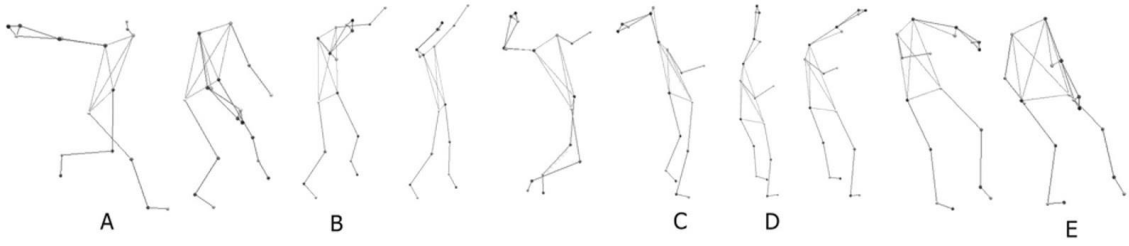


Figure 2.10. Spike Movement Biomechanic in Volleyball. A-B ,1-2: windup phase; B-C,2–4: cocking phase; C-D ,4-8: acceleration phase; D-E,8–9: deceleration and follow-through phase (31)

Continuous repetitive jumps associated with spike, block and spike serve as the basic volleyball skills are characterized by the same muscle activation pattern. The concentric movement of the muscles working during the propulsive phase is prepared by the previous eccentric movement during the preparatory phase. A strong thrust is only possible when the transition phase between the eccentric boot and reflex concentric activation is short and the angular displacement of the knee and ankle joints is small (5,8).

Biomechanically, there are three different jump patterns: drop jump, countermovement jump and squat jump. Drop jump, where the player falls from a height and returns to the air rapidly, not only the most performed during the jump training, but also characterizes the rapid repetitive block jumps requested from the intermediate players. Drop jump is considered a reactive jump with eccentric and concentric phases. Squat jumps are usually performed by block players who must react quickly to an opponent's attacks. The countermovement jump is determined by the classic spike jump, in which the athlete completes his approach with a final step, and then loads the quadriceps and the calves eccentrically after flexion on the hips, knees and ankles with the concentric activation of the quadriceps and calf muscles (6,29).

After jumping, the player must provide energy transfer from the floor with body control before hitting the ball. Major muscle groups active in functional movement, such as jump, are hamstrings, gluteus, quadriceps and gastrocnemius. These muscles produce the kinetic movement pattern in the hip, knee and ankle joints by working together and transferring energy from the ground towards the upwards. Before jumping, the athlete takes the position known as ‘triple flexion” by flexing the ankle, knee and

hip respectively. This position is the athlete's preparation for maximum power generation. Extension of all joints releases explosive strength known as “triple extension” and raises the athlete's body from the ground (6,20).

The vertical jump can be broken down into four phases, a preparatory (or down) phase, a propulsive (or up) phase, a flight phase and a landing phase. The first two phases occur while the jumper is on the ground. Because the height reached by the jumper’s center of gravity is determined by what the jumper does on the ground (34).

During the preparatory phase, shoulders hyperextend , the hips flex, the knees flex, the ankles dorsiflex and the and the body is lowered, so its potential energy decreases. The segment immediately above the ankle joint is lowered (its motion is downward relative to the ankle joint), so its potential energy relative to the ankle joint decreases. The contraction of the active ankle joint muscle group is eccentric. The ankle joint motion is dorsiflexion, but the muscle contraction is eccentric, so the ankle plantar flexors are the active muscle group. The segment immediately above the knee joint (the thigh) is also lowered relative to the knee joint, so its potential energy relative to the knee joint decreases. The contraction of the active knee joint muscle group is eccentric. The knee extensors are the active muscle group. The segment immediately above the hip joint (the trunk) is also lowered relative to the hip joint, so its potential energy relative to the hip joint decreases. The contraction of the active hip joint muscle group is eccentric, and the hip extensors are the active muscle group (33,34).

During the propulsive phase, the opposite motions occur at each joint: The shoulders flex, the hips extend, the knees extend, the ankles plantar flex and the potential and kinetic energies of all the body segments increase. The contraction of the active muscles at each of the joints is concentric. The ankle plantar flexes, the knee extensors and the hip extensors are active. At the end of the preparatory phase and the beginning of the propulsive phase, the body is rapidly accelerated upward. The joints all experience accelerations at these instances as well (34).

During the landing phase of the jump, tibialis anterior and vastus lateralis muscles are activated eccentrically stabilizing the knee and ankle joints respectively. The eccentric activity of the vastus lateralis muscle plays a role in the landing phase to slow down the flexion movement in the knee joint (26, 35,36) (Figure 2.11).

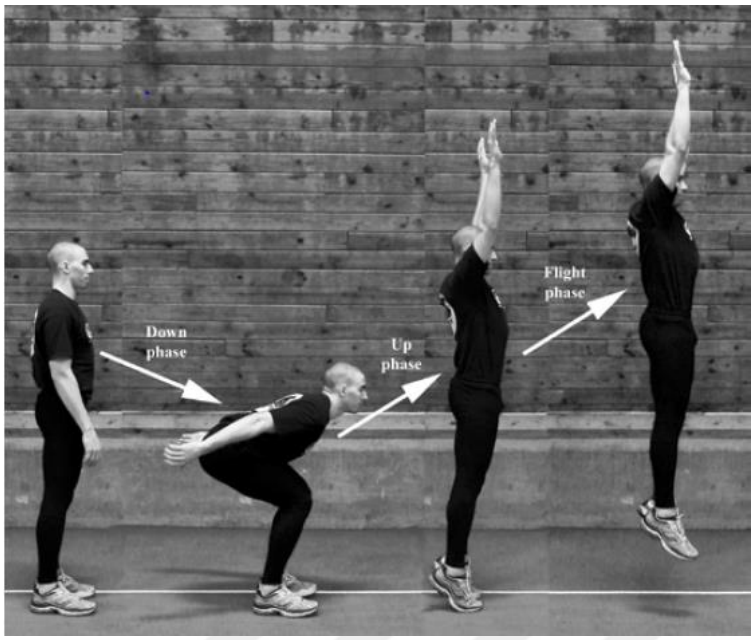


Figure 2.11. Phases of Vertical Jump Movement (34)

2.1.2. Physical fitness parameters and performance in volleyball

In order to gain specific volleyball-specific movements, the athlete needs good physical fitness and some performance factors that he needs to develop (20). Anthropometric properties, technical-tactical skills and physical fitness capacity in volleyball affect the sporting performance of the team. Volleyball sport often requires repeated vertical and horizontal jumps, short and fast runs in different directions, dive-dive&rolls, spikes and blocks (37). In order to be successful in the game, the volleyball player must possess skills such as strength, endurance, quickness, flexibility and speed. A high level of balance, coordination and skill is required for the synchronized and fluent display of basic techniques (10).

Body composition is an important element of physical fitness and is directly related to sports performance (37). All sports branches have physical characteristics with specific age and weight limits. The effect of height and weight on performance is unquestionable. In today's conditions, the taller height of athletes is seen as an advantage for volleyball (12).

2.1.3. Strength

Strength is the talent of a muscle or a group of muscles to resist and withstand a certain level by contracting against a resistance. Strength can be classified as

theoretically (general and special strength), according to training science (maximal strength, quick strength, continuity in strength), according to the type of contraction (dynamic and static strength) (38) .

General Strength: It can be defined as the strength of all muscles, independent of any sports branch.

Special Strength: It is the strength that created by the muscles used to perform specific movements in a certain sport branch.

Volleyball sport has less need for general strength development than other sports. Volleyball player should do the movements as fast as possible and as quickly as possible during the game. In this case, rapid strength and performance continuity in strength gain importance.

Rapid Strength: The rapid strength, the synthesis of strength and speed capabilities, is the talent to exhibit maximum strength in minimum time. In volleyball, rapid strength is the combination of speed and strength in jump and spike movement. Jump strength, hit strength and sprint strength are components of rapid strength.

Continuity in strength: This is the ability of muscles to resist fatique during the training and competitions with long lasting. Strength is very important for volleyball. Leg strength, jumping and arm strength are particularly prominent in spike and block movement, which is frequently used in volleyball (37).

2.1.4. Endurance

Endurance is the athlete's ability to perform the activity for a long time based on long-term static and dynamic loads and physical and physiological fatigue without degrading the quality of work.

Endurance for volleyball is important because the duration of the match is extended by 2-3 hours and a player is asked to perform extra performance during the match (37,38).

2.1.5. Speed

Speed is the ability of the athlete to perform his movements at the highest possible speed (37). In team sports, such as volleyball, the successive change of the offensive and defensive principles at any time accelerates the game and causes athletes to perform sprinting successively (39).

Volleyball is played on an area of 9x9 meters by dividing an 18x9-meter field with a net and explosive sprinting and sudden changes in direction are made at short distances like 3 to 5 meters (40). A successful volleyball player should reach the highest level rapidly and fastly rather than reaching the desired height. This requires the ability to produce power in a very short time (41).

2.1.6. Agility

Agility, a combination of speed and coordination, is the talent to change the direction of the body or parts of the body with average speed and minimum loss of control (37).

Agility is important in volleyball due to the athlete's need to change direction without losing balance and control during the match and training. In volleyball, going for the block towards the direction the ball is coming requires fast and reaction-free agility, such as making moves in changing directions towards the bouncing balls from the block or net (42).

2.1.7. Flexibility

Flexibility, which can also be expressed as the range of motion in the joint or joint array, can also be defined as the talent of a joint to perform at the maximum angle allowed by structures such as shape and structure, muscles, ligaments, tendons and joint capsules (37). Volleyball player with good flexibility means good agility, power and strength. Optimum range of motion in specific joints and flexibility in the surrounding muscles is required to perform well in difficult and unusual positions during a match. Otherwise, injuries are possible (20,43).

2.1.8. Balance

Balance is defined as a rapid and postural adaptation to changes in the center of gravity during rest and activity. This adaptation is achieved by integrating sensory information into the central nervous system (CNS) after gathering them via the visual, vestibular and somatosensory systems, resulting in the formation of appropriate motor responses in the musculoskeletal system (10,44).

The balance can be parted two as static and dynamic. Static balance is the skill to maintain balance while the body is stationary, and dynamic balance is the skill to

maintain the desired posture in motion, and the balance that is important for athletes is dynamic balance (45).

Return to the game position after a successful landing after a jump or sudden change of direction require strength, agility and balance. A meticulous attention to balance must be given since volleyball is an activity that requires explosive and sudden change of direction (46,47).

2.1.9. Coordination (Skill)

Coordination, in other words, skill is the movement produced as a result of the central nervous system and musculoskeletal system working in harmony. Movement coordination is presented as a function of pyramidal and extra pyramidal systems. Coordination is the ability to learn difficult movements in a short period of time and react quickly to the purpose in different situations. In volleyball, jumping for the block is a technique that requires coordination (14,48).

2.2.Plyometric

Plyometric is derived from the Greek words “pleion” and “metric” which mean “more” and “to measure” respectively (10). The plyometric is a Latin word and means measurable improvement (11).

Plyometric is a way to increase sporting performance by exercises with skip, jump and throw methods for strength or explosion. These exercises aim to increase the athlete's explosive reaction with strong concentric contraction after rapid eccentric contraction (36,48). Plyometric exercises rarely last longer than 10 sec when performed correctly (49).

Plyometric exercises are based on a cycle, known as the stretch-contraction cycle, respectively the tension of the muscle-tendon unit and the shortening (concentric contraction) of the muscle-tendon unit before the eccentric contraction of the muscle unit. The stretch-contraction cycle significantly increases the ability of the muscle-tendon unit to produce maximum power in the shortest possible time, which makes it possible to use plyometric exercise as a bridge between pure force and speed (50).

If a sport branch requires movements such as side-to-back swivel movements, running a short distance quickly or sudden direction changes, plyometric exercises are performed to increase the strength in these movements. Plyometric exercises consist of

drills such as different jump drills covering the lower extremities and drills with a medicine ball like equipment covering the upper extremities (36).

2.2.1. Physiology of Plyometric Exercise

Physiological studies supporting the effectiveness of plyometric exercises or the stretch-contraction cycle of muscle tissue indicate the importance of two factors:

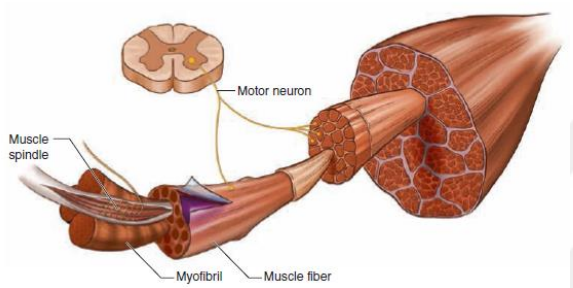
(1) The cross-linking properties of actin and myosin forming muscle fibers and the series elastic components of the muscle including tendons;

(2) Sensors in the muscle spindle (proprioceptors), which play a role in pre-setting muscle tension for the activation of the stretching reflex and in transmitting sensory inputs related to sudden muscle tension (8). The aim of plyometric exercise is to use the stretching reflex and natural elastic components of both muscle and tendon to increase the strength of subsequent movements (51).

The contractile component of the sarcomere of actin and myosin cross-bridges plays an important role in motor control and strength development during plyometric exercises. Plyometric motion uses the pre-tension of the physiological length-tension curve of the muscle-tendon unit to increase the ability of the muscle fibers to produce greater tension and the resulting force product (49). When the active muscle was stretched, it was found that the ratio of cross-bridging separated from actin was decreased the attachment ratio of cross-bridging was increased. Sensory stimulation is sent from the muscle spindle stimulated by the stretching of the muscle, stimulating feedback is provided by the monosynaptic reflex via the same muscle. The magnitude and ratio of the load adjust the tension reflex (14,35,36) (Figure 2.12).

The proprioceptors of the body include the muscle spindle, the golgi tendon organ (GTO) and the mechanoreceptors in the joint capsules and ligaments. Stimulation of these receptors can lead to the facilitation, inhibition and modulation of agonist and antagonist muscles. When the muscle spindle is stretched, there is an increase in firing of afferent nerve. The strength of the signal delivered to the spinal cord from the muscle spindle depends on the rate of stretching applied. The faster the stretching rate, the stronger the neurological signal from the muscle spindle, and finally the greater the efferent muscle contraction (the shortening cycle of plyometric movement). Another mechanical receptor that plays an important role in the plyometric stretch-contraction cycle is GTO. The tendon has been found to be the main contributor to length changes

in muscle-tendon units and the storage of elastic potential energy. The golgi tendon organ, a sensory receptor that lies in the tendon, is stimulated by the stretch of the tendon. Sensory information from the golgi tendon organ synapses onto an interneuron in the spinal cord, and inhibitory feedback is sent to the contracting muscle. Explosive plyometric exercises can improve neural efficiency by increasing neuromuscular coordination. Therefore, plyometric exercise training improves neuromuscular performance by increasing the preset speed of the movable muscles. (35,36,49) (Figure 2.13).



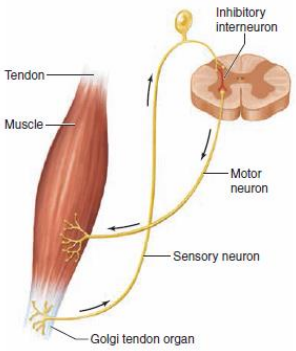


Figure 2.12. Muscle Spindle (35)

Figure 2.13. Golgi Tendon Organ (35)

2.2.2. Phases of Plyometric Exercise

The combination of muscle movements, neural interactions, and connective tissue flexibility facilitating effective plyometric movement can be more easily explained by the stretch-contraction cycle (36). The stretch-contraction cycle is defined as a rapid cyclic muscle movement in which the muscle undergoes an eccentric contraction followed by a transition period before concentric contraction (50). The stretch-contraction cycle consists of three different phases (51) (Figure 2.14).

The first phase of plyometric motion can be classified as loading phase. This phase is also known as the eccentric phase or the deceleration phase (14,52). The loading phase of a plyometric exercise occurs when the muscle-tendon units of the primary moving and synergistic muscle groups are stretched by kinetic energy or joint-induced loading. The loading phase begins when the muscle tendon units begin to perform work that is resistant to gravity or previous movement; this is described as a negative study in the resistance education literature (35). The increase in strength and

performance is achieved by the formation of the stretch-contraction cycle during the loading phase and the tension of the muscle tendon unit (14,53).

The transition between the loading and discharge phase which is the second phase of a plyometric exercise, can be defined as the combination phase. This phase is generally named as the amortization phase and also as the transition phase in the rehabilitation literature. The joint angle, the center of mass and the ground are the phases in which the length of the muscle fibers does not change when the reaction force is about to change direction. The amortization phase is the descriptive phase of plyometric exercise (35,54). This phase is the key to plyometric exercise performance, the shorter amortization phase causes a more effective and powerful plyometric movement, because the stored energy is used efficiently during the transition (55). When the amortization phase lasts longer than 25 milliseconds, there is a measurable reduction in the stored elastic energy (14,31,35).

The discharge phase, which is the third phase of a plyometric exercise, occurs immediately after the combination phase and involves shortening the muscle-tendon unit. In this phase, the muscle shows a rapid elongation that will initiate the stretching reflex during eccentric loading and fires the muscle spindles. This results in the concentric contraction of the muscle namely the agonist extracellular fibers. At this stage, more concentric contraction occurs with faster muscle tension (56).

A. Starting Momentum Load Amortization Discharge Final Momentum

B. SM L A D FM

C. SM L A D FM

Figure 2.14. Plyometric exercise phases in A) Lower Extremity, B) Upper Extremity, C) The trunk (35)

2.2.3. Effects of Plyometric Exercise Training

Plyometric exercises aim to improve performance by causing neuromuscular adaptations. Exercises for rehabilitation may not contribute sufficiently to acquiring sport-specific movements. Therefore, plyometric exercises can build a bridge between the exercises helping an increase in muscular strength specific to sport branch and rehabilitation (54). Plyometric exercises can be in many forms, with a health ball for the upper limb and trunk, and jump for the lower limb (14).

Pliometric exercises can be used not only to break the monotony of training, but also to increase the strength, power and agility of athletes (55). Pliometric exercise training to improve athletic performance parameters is generally continued for 6-15 weeks (56,57). In many studies, it has been found that Plyometric exercise has an effect on jump, athletic performance and sports skills. In the research conducted for athletic performance, increase in vertical jump, decrease in sprint time was found (58). The study conducted on female athletes has also been claimed that plyometric exercises reduce the risk of injury by correcting neuromuscular imbalance (14,59).

Several studies have reported that high intensity and volume field plyometric exercises can cause muscle damage, muscle injuries and musculoskeletal injuries, as well as many positive effects (60).

3. MATERIAL AND METHODS

3.1.Subjects

This study was conducted with the volleyball players of Sarıyer City Hall Sports Club to investigate the effect of six-week plyometric exercises on running, jumping, throwing and dynamic balance capacities of female volleyball players.

The study included in 35 volleyball players and the subjects who met inclusion criteria. The subjects who participated in the study were randomly controlled and divided into first and second groups.

3.1.1. Inclusion Criteria

- Athletes should be between the ages of 14-18,
- The athletes have consent to the participation and has a consent form signed by the family.

3.1.2. Exclusion Criteria

- Years spend in the sport are less than 5 years,
- Having orthopedic / systemic disease during exercise training,
- The athlete does not participate in exercise training for more than 3 sessions,
- Having suffered lower / upper extremity injuries in the last 3 months.

This study was approved by the Medical Ethics Committee of Medical, Surgical and Drug Researches of Yeditepe University Faculty of Medicine (Meeting Date: 27.02.2019, Decision Number: 1579). Each individual and his / her parents were informed about the content of the study and read and signed the participant consent form and the parental consent form indicating that they voluntarily participated in the study (Appendix A).

3.1.3. Flow of Research

A total of 35 female volleyball players between the ages of 14 and 18 who participated in the same strength and training program were included in the study. As for the first step, we separated the subjects according to simple randomization method.

While the subjects odd survey number involved the pliometric exercise training with the classical volleyball training group (G1) (n=18) and the subjects with the even survey number involved the classical volleyball training group (G2) (n=17). During the evaluations and trainings, 5 subjects were excluded from the study according to exclusion criteria and the study was terminated with a total of 30 players (Figure 3.1).

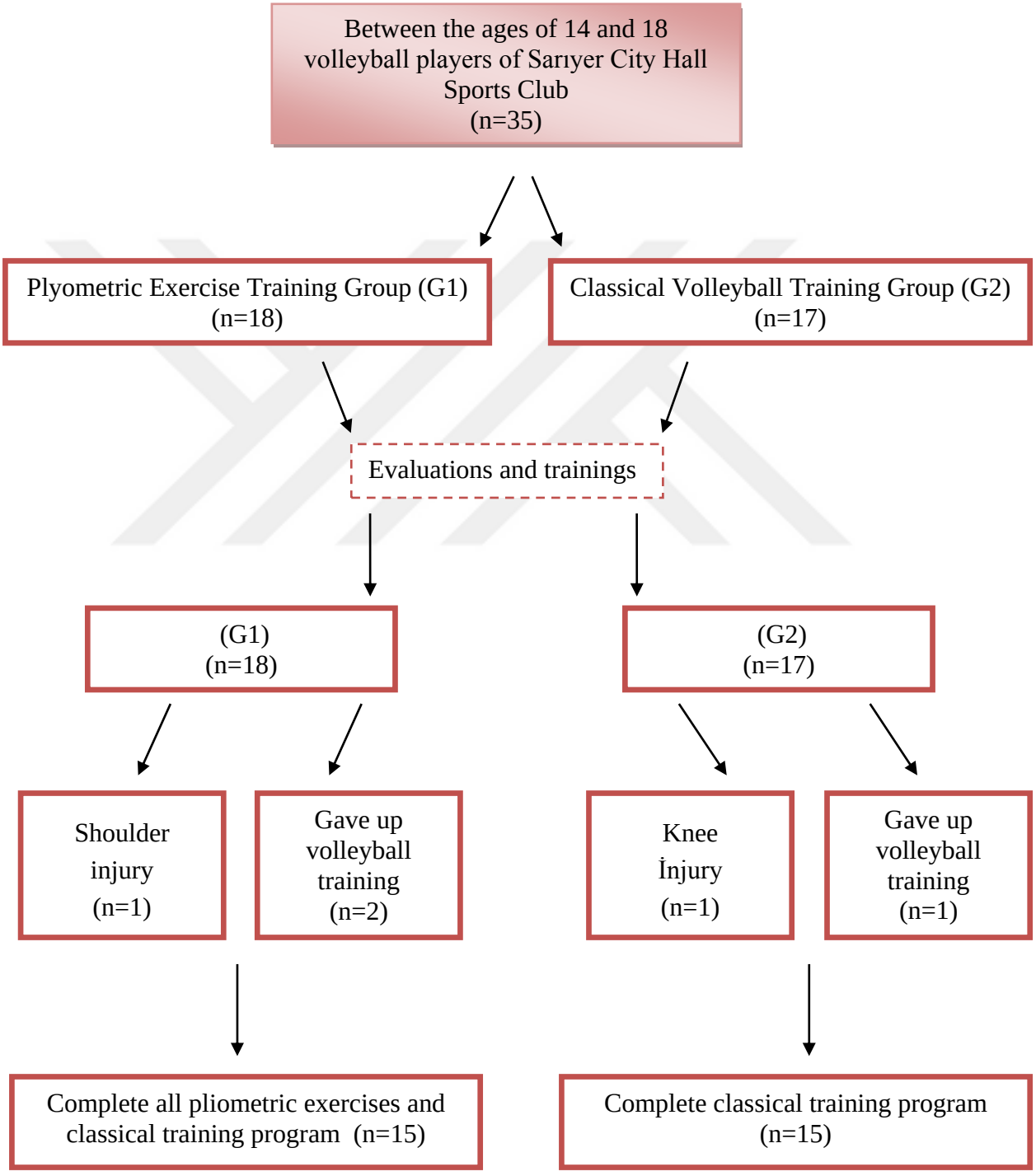


Figure 3.1. Flow Chart

3.2 METHODS

Before starting the study, a verbal presentation was made to inform the subjects about the plyometric exercise program. The purpose of the study and the content of the plyometric exercise training program were explained to all subjects in accordance with the participant consent form.

The demographic information of all subjects who volunteered to participate in the study was questioned with a questionnaire and field tests in the research criterion were performed (Appendix B).

Following the evaluation, the subjects in the first group were taken to the plyometric exercise training program with the same physiotherapist twice a week for 6 weeks in addition to the classical volleyball training programs. The subjects in the second group continued their classical volleyball training programs for 6 weeks.

3.2.1 Evaluation

Evaluations were made before and after the training, on the day of rest of both groups. G2 was subjected to the same measurements and tests before and after the study. After the six-week plyometric exercise training program, the same tests were performed again and the pre-test and post-test results of the two groups were compared.

3.2.1.1 Demographic Information

Before starting the study, the general descriptive characteristics of the subjects were recorded in the demographic information form which are date of birth, lower and upper extremity dominant side, height, body weight, volleyball age, and history of injury in the last 3 months. Subjects who did not meet the inclusion criteria were excluded from the study.

3.2.1.2 Field Tests

Field tests of the subjects before and after the training were conducted in the same environment. Before the assessment tests, the subjects were given 10-minute warm-up exercises, and the appropriate resting time was given for each test.

3.2.1.2.1 Vertical Jump

In the measurement of the test, the highest point where the athlete could reach with his hand on the meter by standing side to the wall, was marked and recorded as the first measurement of the test. After chalking his hand, the athlete jumped up as much as he could and touched the top of the meter with his hand and the value was recorded as the second measurement of the test. The measurement was repeated 3 times and the maximum value of the second measurement jumps was recorded. The vertical jump value was found with the difference between the second measurement value of the athlete and the first measurement given at the beginning of the test and was recorded in cm. Vertical jump test of athletes was performed without shoes (12,61,62) (Figure 3.1).

Figure 3.2. Vertical Bounce Test

3.2.1.2.2. Medicine Ball Throw Test

The medicine ball throw test is a test used to measure the explosive strength of the upper extremity and trunk (63).

The athlete took the position of both toes at the starting line as she holds the 3 kg medicine ball grasped with both hands at chest level. The athlete was asked to throw the medicine ball in the horizontal direction with the chest pass using both hands as far as possible. During the throw, the body was not allowed to swing back and step forward and the athlete was informed. The physiotherapist marked the point where the ball

touched first. The test was repeated 3 times and the best value was recorded (64,65) (Figure 3.2).

Figure 3.3. Medicine Ball Throw Test

3.2.1.2.3. 20 meters Sprint Test

It is a test to evaluate the speed performance of athletes. The lines indicating the beginning and end of the measured 20 meters are indicated by funnels. The athlete was instructed to place their preferred foot ahead at the starting line marked on the ground and run as fast as possible through the test distance. The test was repeated 3 times and the average time was recorded in seconds. Measurements were performed with 2-minute rest (14,64) (Figure 3.3).

Figure 3.4. 20M Sprint Test

3.2.1.2.4. Y Balance Test

Dynamic balances of the athletes were evaluated by Y balance test. The three directions extending from the peak point on the ground were determined by a straight line indicated by a tape measure and tape measure pasted at an angle of 135 degrees to this line (65). The athletes were asked to reach the longest distance they could reach in three directions, anterior, postero-medial and postero-lateral, with the other foot as their hands on their waist standing on their preferred foot, so that they keep their balance. The measurement was canceled and repeated if the individuals were disoriented and had support from the ground with the foot on the reached side during reaching out to the farthest distance. Extensions were repeated 3 times in all directions and the average of 3 measurements was taken. Resting time between stretches was given as one minute. For normalization of the test, the leg lengths of each individual (the distance between spina iliaca anterior superior and medial malleol) were measured in the supine position. The result was recorded as (length of reach / leg length) x 100 (67) (Figure 3.4).

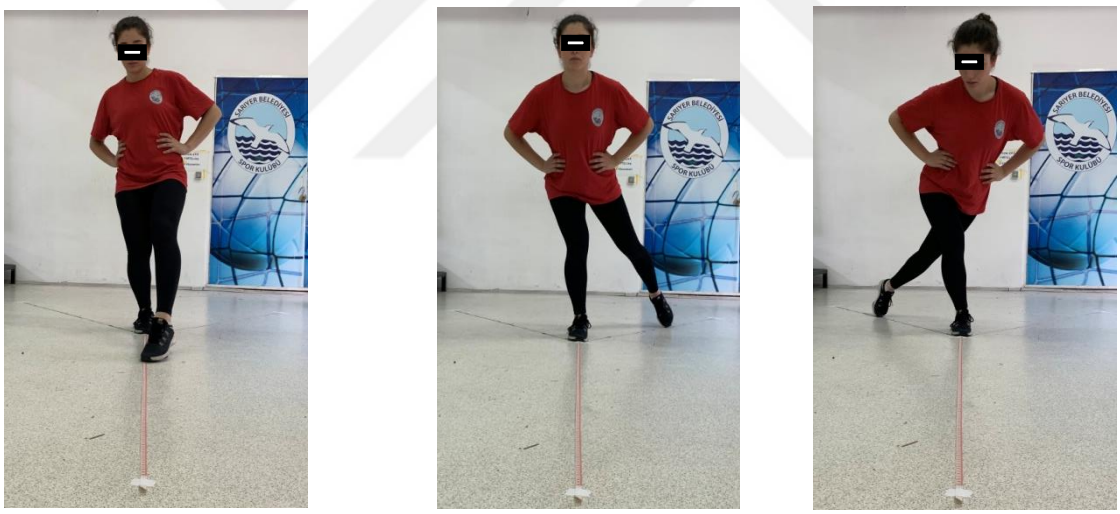


Figure 3.5. Y Balance Test; Anterior, Posteromedial, Posterolateral

3.2.2. Study Protocol

3.2.2.1.Plyometric Exercise Training Program

The two groups included in the study continued their tactical and strength training during the season following the evaluations. The subjects in the first group were taken to the plyometric exercise training program with the same physiotherapist twice a week for 6 weeks in addition to the classical volleyball training programs. The first group participated in a plyometric exercise session with 10 minutes of warm up,

30-40 minutes of Plyometric exercise and 10 minutes of cool down - stretching. There was a 30 sec break between sets and a 2-minute break between exercises. Exercises were planned as 6 movements (lower extremity and upper extremity) and the degree of movements from easy to difficult. After the exercises determined in the first week, the easy exercise was removed from program in the second week and a more difficult exercise program was added and the variety number of exercises was kept as three for both lower and upper extremities (14,47,68).

Running and short-term stretching exercises were performed in warm-up. Stretching exercises were instructed for anterior-posterior-inferior capsule, right left trapezoidal muscle, lattisimus dorsi muscle, hip flexor muscles, lumbar extensors, hamstring, quadriceps, hip adductors, priformis and gastrocnemius muscles. After the exercises, low-intensity running and static stretching exercises were performed (14,20).

3.2.2.2.Classical Training Program

All athletes included in the study continued their classical training programs for 2 - 2.5 hours for 6 weeks, 6 days a week.

The content of classical training program;

Technical-tactical (ball) training: 6 days,

Strength training: 2 days,

Warm-up (10 min): Drills in the form of short-term dynamic stretching exercises following light-paced running or low-intensity aerobic activities,

Cool Down (10min): Static stretching exercises followed by walking or jogging.

Table 3.2.2.1. Plyometric Exercise Training Program

EXTREMITY – NAME OF EXERCISE	**WEEK, NUMBER OF REPETITIONS and SET**					
UPPER EXTREMITY	**WEEK 1**	**WEEK 2**	**WEEK 3**	**WEEK 4**	**WEEK 5**	**WEEK 6**
1. CHEST PASS	5*3					
2. OVERHEAD THROW	5*3	5*3				
3. BACKWORD THROW	5*3	5*3	5*3			
4. ROTATIONAL TROW		6*3	6*3	6*3		
5. MEDICINE BALL ONEHAND THROW			5*3	5*3	5*3	
6. OVERHEAD SIT- UP TOSS				6*3	6*3	6*3
7. BURPEE TO MEDICINE BALL					5*3	5*3
8. JUMPING SPIDER						5*3
LOWER EXTREMITY	**WEEK 1**	**WEEK 2**	**WEEK 3**	**WEEK 4**	**WEEK 5**	**WEEK 6**
1. DOUBLE LEG VERTICAL JUMP	5*3					
2. DOUBLE BUTT KICK	5*3	5*3				
3. HEXAGON DRILL	12*3	12*3	12*3			
4. BROAD JUMPS		5*3	5*3	5*3		
5. LATERAL BOX SUFFLES			5*3	5*3	5*3	
6. STANDING LONG JUMP WITH LATERAL SPRİNT				6*3	6*3	6*3
7. DIAGONAL CONE HOPS					5*3	5*3
8. DEPTH JUMPS						5*3

3.2.3. Upper Ekstremity Plyometric Exercises

3.2.3.1.Medicine Ball Chest Pass

Stand with partner at the throwing distance. One of the partners holds the medicine ball with a hand next to his head. The other partner is ready to hold the ball in front of the ball. First person throws medicine ball just above partner's head forcefully, Partner catches ball with both hands, immediately throws ball back to first person in the same manner. First person catches ball and repeats. This plyometric exercise is low-intensity (35,69) (Figure 3.6).

Figure 3.6. Chest Pass

3.2.3.2.Medicine Ball Overhead Throw

Stand front of the wall throwing distance. The ball is lifted over the head bending the arms and is throwed to wall forcefully. Catch the ball and repeat volley. Keep throwing the ball forward. This plyometric exercise is low-medium-intensity (35,69) (Figure 3.7).

Figure 3.7. Overhead Throw

3.2.3.3.Medicine Ball Overhead Backward Throw

Feet are standed more open than shoulder width. The ball is held overhead between hand and is lowered with arms straight in long forward arch motion. The ball is swinged down between both legs and is thrown back and upward. This plyometric exercise is low-medium-intensity (35,70) (Figure 3.8).

Figure 3.8. Backward Throw

3.2.3.4.Medicine Ball Overhead Throw Sit-up

The first person, sits on floor with knees bent. The ball is held between two hands. Lie back with ball over head and taps ball to floor. Immediately the ball is thrown to partner from over head while sitting up. Partner catches the ball slightly when standing and throws again. This plyometric exercise is medium-high-intensity (35,65) (Figure 3.9).

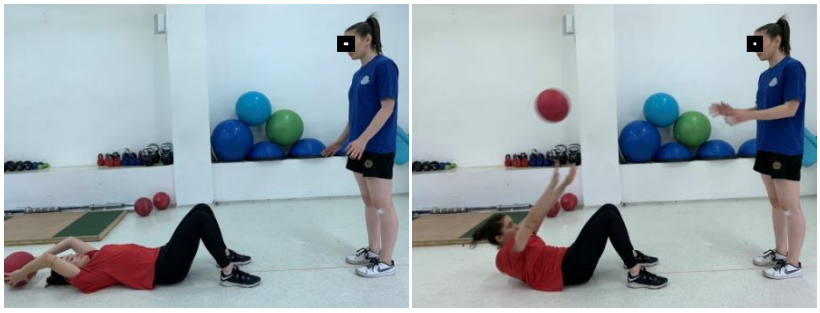


Figure 3.9. Overhead Sit-up Toss

3.2.3.5.Medicine Ball One Hand Throw

The partners are stood throwing distance with left foot forward. One of the partners holds the ball next to his head with his right hand. Other partners has arm up

ready to receive ball. The ball is thrown by first person to left of partner's head (partner's right side), forcefully extending arm forward. Partner catches the ball with both hand, recoils ball to side of head, and immediately throws ball back to left of first person's head (first person's right side) with right hand. First person catches ball and repeats throw. This plyometric exercise is medium-intensity (35,65) (Figure 3.10).

Figure 3.10. One Hand Throw

3.2.3.6.Medicine Ball Rotational Throw

The person stand with side of body facing wall. The ball is hold at waist level. When squat down and ball is positioned to side of far hip by rotating shoulders and slightly arms are bent away from wall. Quickly rotate torso toward wall driving with legs, hip, waist, and far arm in a slightly upward angle. Release ball so it hits wall approximately head height. Quickly step far foot forward so body faces wall with feet approximately shoulder width apart. Catch ball and immediately step opposite leg back so other side faces wall. This plyometric exercise is medium-intensity (35,71) (Figure 3.11).

Figure 3.11. Rotational Throw

3.2.3.7.Burpee To Medicine Ball Chest

Start when the medicine ball is standing a couple feet in front of you. With your feet about hip-width apart, squat down is made and the hands are put on the medicine ball while simultaneously jumping your feet out into a plank position. Quickly the feet is jumped out into a wide squat stance, the ball is picked up, and is pressed it forward, away from your chest. This plyometric exercise is medium-high-intensity (35,68) (Figure 3.12).

Figure 3.12. Burpee To Medicine Ball Chest

3.2.3.8.Jumping Spider Push-up

Start in a high plank position with your hands outside your chest and your body in a nice straight line. When doing plank then knee is brought up in toward the outside of your elbow, placing your foot on the ground. Then quickly press back up, and as you do, explode up off the ground to land with your other hand staggered back and your other knee in by your elbow.Explode back up off the ground and land back on the first side. This plyometric exercise is high-intensity (35,65) (Figure 3.13).

Figure 3.13. Jumping Spider Push-up

3.2.4. Lower Extremity Pliometric Exercises

3.2.4.1.Double Leg Vertical Jump

Feet are standed more open than shoulder width. Squat down is made and jumped up as high as possible. With one or both hands are reached upward. Upon landing, instantly jump up again and try to reach higher. This plyometric exercise is low-intensity (35,72) (Figure 3.14).

Figure 3.14. Double Leg Vertical Jump

3.2.4.2.Broad Jumps

The feet are held open with a shoulder width. Squat down is made partially and the arms are raised forward. The arms are swinged back behind sides and is leaned forward. Rapidly when the arms are swinged forward and is jumped forward as far as possible with both feet close together. Land with both feet together with legs are bend and standed up. This plyometric exercise is medium-intensity (35,65) (Figure 3.15).

Figure 3.15. Broad Jumps

3.2.4.3.Double Butt Kick

Feet are standed more open than shoulder width. Squat down is made slightly with feet flat on floor by bending knees and hips. Jump up and kick back of heels toward buttocks. Land on both forefeet and repeat. This plyometric exercise is low-medium-intensity (35,73) (Figure 3.16).

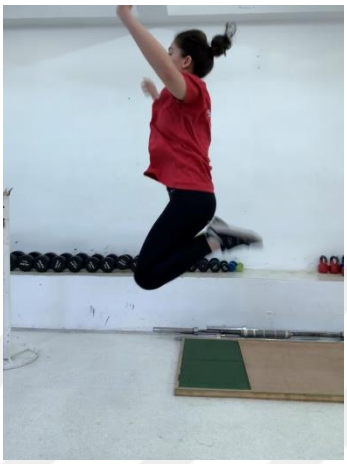


Figure 3.16. Double Butt Kick

3.2.4.4.Lateral Box Sufflex

With one foot is stood on box and other foot off, down by side of box. Jump sideways so opposite foot is on box and the other is off by side of box. Repeat side to side. This plyometric exercise is medium-intensity (18,35) (Figure 3.17).

Figure 3.17. Lateral Box Sufflex

3.2.4.5.Depth Jumps

Feet are standed more open than shoulder width. With both feet is steped off box landing and the person is jumped off the ground as fast as possible. With one or both hands are reached upward.This plyometric exercise is high-intensity (35,74) (Figure 3.18).

Figure 3.18. Depth Jumps

3.2.4.6.Hexagon Drill

With one foot is stood in the center of the hexagon. With one foot is jumped across one side of the hexagon and back to center, then proceed around each side of the hexagon. Do it again with your other foot. This plyometric exercise is low-medium-intensity (35,55) (Figure 3.19).

Figure 3.19. Hexagon Drill

3.2.4.7.Standing Long Jump Lateral Sprint

The feet are stood in a semisquat shoulder-width apart. Using a big arm swing, perform a standing long jump. Land on both feet, trying to stay upright. Instantly sprint laterally (right or left) for 3 meters. This plyometric exercise is medium-high-intensity (35,65) (Figure 3.20).

Figure 3.20. Standing Long Jump Lateral Sprint

3.2.4.8.Diagonal Cone Hops

The feet is stood together at the end of the line of barriers. With one foot, jump in a zigzag fashion across the barriers, moving down the line. Land on ground with one foot , and use a double-arm swing to stabilize the body movement. Do it again with your other foot. This plyometric exercise is medium-high-intensity (35,75) (Figure 3.21).

Figure 3.21. Diagonal Cone Hops

3.2.5. Data Analysis

The data obtained from the athletes were analyzed using the SPSS for IBM Version 21 statistical package program.

The Wilcoxon Test was used to analyze the pre- and post-training findings of the study and control groups. The means of the variances were shown as arithmetic mean ± standard deviation (mean ± SD).

Mann - Whitney U Test was used to compare the differences between the study and control groups before and after training between the groups. The means of the variances were shown as arithmetic mean ± standard deviation (mean ± SD). In all statistics, p value of significance was taken as $p < 0.05$ and expressed as (20).

4. RESULTS

4.1. Descriptive Data and Evaluation Results

The aim of this study was to investigate the effects of six-week plyometric exercises on running, jumping, throwing and dynamic balance capacities of 30 female volleyball players with median age of 16,43±1,47. The age, height, weight and BMI characteristics of the athletes included in the first group (G1) (n=15) were given plyometric exercise program in addition to the classical training program during the process and the second group (G2) (n=15) performing the classical training program. There was no statistically significant difference between the two groups in terms of age and physical characteristics (height, body weight and BMI) (p> 0.05).

Table 4.1 Comparison of physical properties of groups

Demographic Features	**G1**	**G2**		
	mean±SD (min-max)	**mean±SD (min-max)**	**T**	**p**
Age (years)	16,53±1,45 (14-18)	16,33±1,49 (14-18)	0,37	0,71
Height (m)	1,77±0,07 (1,6-1,86)	1,74±0,06 (1,65-1,88)	1,28	0,20
Weight (kg)	67,38±6,48 (57-79)	68,50±4,62 (61,1-78,4)	-0,54	0,59
Body Mass Index (kg/m²)	21,39±1,86 (19,08-24,45)	22,58±1,94 (20,65-28,80)	-1,70	0,09

Intergroup vertical jump, ball throwing, 20 m sprint and Y balance test pre intervention values are presented in Table 4.2 and Table 4.3. There was a statistically difference between the two groups in terms of vertical jump test and right-left anterior and posterolateral direction of Y balance test values (p< 0.05).

Table 4.2 Intergroup Vertical Jump, Throwing Ball, 20 m Sprint Test Pre-intervention Values

Test	G1	G2		
	mean±SD	mean±SD	T	p
Vertical Jump (cm)	37,93±6,34	26,4±4,92	5,53	**0,00**
Throwing Ball (m)	5,85±0,87	6,25±0,13	-1,50	0,14
20m sprint (sn)	3,35±0,30	3,39±0,30	-0,40	0,68

Table 4.3 Intergroup Y Balance Test Pre-intervention Values

Y Balance Test		G1	G2		
		mean±SD	mean±SD	t	p
Right (dominant)	**Anterior (cm)**	75,29±7,79	97,22±14,11	-5,26	**0,00**
	Posteromedial (cm)	108,69±10,83	100,99±12,82	1,77	0,08
	Posterolateral (cm)	105,78±11,98	92,95±14,60	2,63	**0,01**
Left (non dominant)	**Anterior (cm)**	76,96±7,32	95,46±13,76	-4,59	**0,00**
	Posteromedial (cm)	109,55±11,43	101,15±13,78	1,81	0,08
	Posterolateral (cm)	105,39±11,64	94,88±13,90	2,24	**0,03**

Intragroup statistics of jump, throw, running and Y balance tests values of subjects pre-plyometric and post-plyometric training for G1 are given in Table 4.4 and Table 4.5. In the first group, there was a statistically significant difference pre and post training in vertical jump and ball throw values between the right anterior and

posteromedial and left anterior, posteromedial and posterolateral values of the Y balance test ($p < 0.05$). There were no significant difference for 20 m running and right posterolateral value of Y balance test ($p > 0.05$).

Table 4.4 Intragroup Variables of Pre and Post Findings of The First Group Vertical Jump, Ball Throwing and 20 M Sprinting Test

Test	G1			
	Pre mean±SD	**Post mean±SD**	**t**	**p**
Vertical Jump (cm)	37,93±6,34	39,60±6,33	-5,49	**0,00**
Throwing Ball (m)	5,85±0,87	6,15±0,80	-3,87	**0,00**
20m Sprint (sn)	3,35±0,30	3,38±0,37	-0,76	0,46

Table 4.5 Intragroup Variables of Pre and Post Findings of The First Group Y Balance Test

Y Balance Test		G1			
		Pre mean±SD	Post mean±SD	t	p
Right (dominant)	Anterior (cm)	75,29±7,79	79,82±9,46	-6,04	**0,00**
	Postero medial (cm)	108,69±10,83	113,22±13,49	-2,90	**0,01**
	Postero lateral (cm)	105,78±11,98	106,48±11.19	-0,35	0,72
Left (non dominant)	Anterior (cm)	76,96±7,32	80,66±6,77	-6,06	**0,00**
	Postero medial (cm)	109,55±11,43	113,45±13,50	-3,35	**0,00**
	Postero lateral (cm)	105,39±11,64	110,32±12,42	-3,61	**0,00**

Intragroup statistics of jump, throwing, running and Y balance values of subjects pre and post classical training for G2 are given in Table 4.6 and Table 4.7. In the second group, a statistically significant difference was found between the right anterior, posteromedial and posterolateral, and left anterior and posteromedial values of Y balance test and the throwing ball before and after training ($p < 0.05$). There was no significant difference in left posterolateral value of Y balance test with 20 m sprint and vertical jump ($p > 0.05$).

Table 4.6 Vertical Jump, Ball Throwing and 20 M Sprinting Test Pre and Post Findings Intragroup Variables in Second Group

Test	G2			
	Pre mean±SD	**Post mean±SD**	**t**	**p**
Vertical Jump (cm)	26,4±4,92	26,8±5,14	-0,79	0,44
Throwing Ball (m)	6,25±0,13	6,31±0,13	-10,66	**0,00**
20m sprint (sn)	3,39±0,30	3,39±0,29	0,31	0,75

Table 4.7 Intragroup statistical analysis of Y balance test Pre and Post Findings of Second Group

Y Balance Test		G2			
		Pre mean±SD	**Post mean±SD**	**t**	**p**
Right (dominant)	**Anterior (cm)**	97,22±14,11	98,87±13,91	-5,48	**0,00**
	Postero medial (cm)	100,99±12,82	103,03±13,61	-3,47	**0,00**
	Postero lateral (cm)	92,95±14,60	96,18±14,23	-6,62	**0,00**
Left (nondominant)	**Anterior (cm)**	95,46±13,76	97,96±13,16	-5,80	**0,00**
	Postero medial (cm)	101,15±13,78	102,89±13,64	-2,63	**0,02**
	Postero lateral (cm)	94,88±13,90	96,32±13,84	-1,82	0,08

Comparison of vertical jump, ball throwing, 20 m sprint and Y balance values are presented on Table 4.8 and Table 4.9. While the vertical jump and throwing ball difference values increased in G1 compared to G2 ($p < 0.05$), no statistically significant difference was found when the 20 m sprint difference values were compared ($p > 0.05$). When the pre and post Y difference values are compared between the groups, there was a statistically significant difference in right anterior and posteromedial as regards in G2 ($p < 0.05$), but there was no statistically significant difference between right posterolateral and left anterior, posteromedial and posterolateral ($p < 0.05$).

Table 4.8 Comparison of Pre and Post Jump, Throwing and Sprinting Test Values of Intergroup Variables

Test	G1	G2		
	mean±SD	mean±SD	u	p
Vertical Jump (cm)	0,01±0,01	0,00±0,01	2,56	**0,01**
Throwing Ball (m)	0,29±0,29	0,05±0,02	-4,57	**0,00**
20m sprint (sn)	0,03±0,18	-0,00±0,03	-1,91	0,05

Table 4.9 Comparison of Pre and Post Y Balance Test Values of Intergroup Variables

Y Balance Test		G1	G2		
		mean±SD	mean±SD	u	p
Right (dominant)	Anterior (cm)	75,29±7,79	1,65±1,16	-3,60	**0,00**
	Posteromedial (cm)	4,52±6,03	2,03±2,26	-2,28	**0,02**
	Posterolateral (cm)	0,69±7,61	3,22±1,88	-0,99	0,31
Left (non dominant)	Anterior (cm)	3,70±2,36	2,50±1,66	-1,24	0,21
	Posteromedial (cm)	3,89±4,49	1,74±2,55	1,61	0,11
	Posterolateral (cm)	4,92±5,27	1,43±3,04	-1,59	0,11

4. DISCUSSION

In this study, according our result we found that the effects of 6-week plyometric exercises on running, jumping, throwing and dynamic balance capacities of female volleyball players were investigated. Plyometric exercise training program had positive effects on vertical jump, ball throwing, right anterior and posteromedial balance. In the first group, vertical jump, ball throwing, right anterior and posteromedial and left anterior, postermedial and posterolateral balance parameters were improved after the training.

The study was conducted with 30 volunteer female volleyball players between the ages of 14-18. There was no difference in age and physical characteristics (body weight, height, body mass index) parameters of the intergroups. In summary, the study was conducted with two homogeneous groups in terms of physical characteristics of the subjects.

Studies on plyometric exercises have shown that plyometric exercises of different types and severities significantly improve jump performance. We found that a statistically significant difference was found in the comparison of the measurements related to the vertical jump performance pre and post plyometric exercise training program applied to the volleyball players participating in our study.

Pereira et al. (2011) investigated the effect of plyometric exercise training on vertical jump in female volleyball players in a study. Plyometric exercise training program was applied to the study group for 8 weeks, 2 days a week and both groups continued strength and classical training programs at the same time. The vertical jump was increased in the study group and no change was observed in the control group (15,76).

Trajkovic et al. (2016) investigated the effect of 6-week Plyometric training on dunk jump kinematic parameters (angular and linear velocity) in female volleyball players with a mean age of 16 years. Significant improvement was observed in the study group compared to the control group and it was stated that Plyometric training could improve the movement and performance of the athlete and reduce the risk of injury (18).

Kristicevic and Krakan (2016) reported that with the Plyometric exercise training lasting 1 day and 5 weeks per week, there was an increase in the vertical jump

of the study group and no significant improvement in the control group in female volleyball players (17).

In the study conducted by Ramirez-Campillo and his friends with football players, the players were divided into 3 groups; control group, PE24 and PE48 Groups that the exercises were performed between 24 hours and 48 hours rest. They investigated the effect of plyometric exercises performed twice a week for 6 weeks on jump and running performance parameters. In the control group, no improvement was observed in the related parameters, but there was an increase in the study groups with a difference in resting time, and there was no significant difference between them (76).

It has been proven in accordance with the studies that programmatic, regular and correctly applied plyometric exercises in sports branches (football, volleyball, basketball, handball, weightlifting) had an important role in the jump and the explosive feature and the development of explosive power has a positive impact on performance (77).

In the present study, the related parameter also increased in both groups, whereas in the evaluation of the groups, the increase in our first group was higher than the second group.

In their study with volleyball players, Gjinovci et al. examined the effect of 12-week Plyometric exercises and volleyball skill-based training on running, jumping and throwing capacities. While significant changes were observed in both groups, they stated that the plyometric exercise training group had more effect on the development of capacities than the volleyball skill based group (68).

Ignjatovic et al, examined the effect of 12-week plyometric-based exercises performed with medicine ball on the upper extremity muscle strength in the study conducted on handball players with a mean age of 16 and standing and seated 1 kg and 3 kg medicine ball throw and bench and shoulder press tests were used. They reported significant increases in the study group compared to the control group (78).

In the researches, throwing ball tests can be performed over the head to forward, backward as well as seated, on the knee and standing, and the above studies have used the same test as our study and the results have been found to support our study.

No statistically significant difference was found in the comparison of 20 m sprint measurements taken pre and post plyometric exercise training program.

Alptekin et al. investigated the effect of 8-week plyometric exercises on sprint and jump performance in soccer players with a mean age of 13 years and no significant difference was found on sprinting (79).

Slimani et al.'s the systemic article and many studies investigating the effect of plyometric exercise in team sports athletes on the sprint parameter, significant improvements has been proven (80).

In the present study, increases were observed in the dynamic balance parameter in the dominant right side anterior and posteromedial of the first group compared to the second group, while no significant difference was found in the anterior, posteromedial and posterolateral and right side posterolateral directions of the non-dominant left side.

Bouteraa et al. investigated the effect of 8-week combined plyometric and balance exercises on physical fitness parameters in female basketball players. In the Y balance test performed only on the dominant side, significant increases were found in all three directions in the study group (81).

In another study by Abbas et al. (2015) in which the effects of plyometric training given on the balance parameter for 6 weeks in basketball players for 2 days a week, star balance test on dominant side was used. At the end of the training, an increase was observed in all directions except the posteromedial and posterolateral aspects in the study group (82).

Turgut et al. (2018) studied the effect of plyometric exercises on dynamic balance bilaterally in volleyball players with an average age of 11 years. They stated that there was an increase in both dominant and non-dominant sides in the study group, whereas there was no significant difference between the dominant and non-dominant sides of the control group (83).

The information in the literature supports our study and the increase in the values of the dominant right side anterior and posteromedial values of the players in the first group may be caused by the players. The balance parameter that is dominant or not and not increased in the posterior direction may be the absence of posterior movements in the given exercise protocol or the exercises given in plyometric training are mostly in anterior, medial and lateral directions.

The limitations of our study;

- We could be consider that the 20 m sprint test, which evaluates the speed performance after the training, does not differ between the first and second group measurements, and the speed and quickness exercises performed at the beginning of the technical-tactical trainings are effective in improving the speed parameter in the second group athletes.
- As a result of statistical analysis before the training, some direction of y balance test and vertical jump parameters intergroups were not similar.
- The number of players has been kept few because the volleyball training program implemented by different coaches of different clubs will affect the work.

5. CONCLUSIONS AND RECOMMENDATIONS

Our study was conducted with 30 professional female volleyball players to investigate the effect of plyometric exercise program on running, jumping, throwing and dynamic balance capacities. The effectiveness of the pliometric exercise program, which progresses from low intensity to high intensity, has been demonstrated in increases in vertical jump, throwing and some directions of dynamic balance. Our study shows that short plyometric exercises training (6 weeks) has the potential to enhance jumping, throwing and dynamic balance in young female volleyball players.

With the Plyometric exercise training, significant improvements were found in explosive strength parameters such as in the capacity of vertical jump and throwing ball. These results imply that plyometric exercise training could be more effective to improve performance especially in volleyball players during jump and throwing.

REFERENCES

1. Aslan, T. 10-14 Yaş Grubundaki Kadın Voleybol Oyuncularda Ağırlık Yelekli ve Yeleksiz Pliometrik Antrenmanların Dikey Sıçrama Performansına Etkisi. (2013).

2. Gaz, C. *et al.* Voleybol oyuncularinda farkli kuvvet antrenmanlarinin statik ve dinamik denge yetenekleri üzerine etkisi. (2017).

3. Yildirim, T., Tez, S. & Dan, D. " Liseli Erkek Voleybolcularda Sekġz Haftalik Pliometrik Antrenman Programinin Seçilmiş Fiziksel Ve Fizyolojik Parametreler Üzerine Etkisi ". (2010).

4. Tez, S. & Sadak, E. YÜKSEK LİSANS TEZİ Elif SADAK 2018. (2018).

5. Eom, H. J. & Schutz, R. W. Statistical analyses of volleyball team performance. *Res. Q. Exerc. Sport* (1992): **63**, 11–18.

6. Uzun, E. Skapular Diskinezisi Olan Voleybol Oyuncularında Kinezyo Bantlamanın Omuz Mobilite ve İzokinetik Kuvvete Etkisi. (2015).

7. İşler, S. Basketbol ve Voleybolcularda Deltoid Kas Kantitatif EMG Aktivasyonunun İzokinetik Kuvvete Etkisi. (2018).

8. İnce, T. Genç Futbolcularda Pliometrik Antrenman Programının Sportif Performans Parametrelerine Etkisi. (2018).

9. Demir, Y. K. Statik Germe Uygulamalarının Voleybol Oyuncularının Dikey Sıçrama Çeviklik ve Sürat Performansına Olan Akut Etkileri. (2018).

10. Kılıç, R. T. Farklı Spor Branşlarındaki Sporcuların Denge Performans Parametrelerinin Tanımlayıcı Özelliklerinin Belirlenmesi. (2018).

11. Adıgüzel, N. S. Sekiz Haftalık Pliometrik Antrenmanın 15-18 Yaş Grubu Basketbolcularda Sıçrama ve İzokinetik Kuvvet Parametreleri Üzerine Etkisi. (2017).

12. Tez, S. & Dem, E. VoleybolculariFizikselParametreleriÜzerine. (2016).

13. Luebbers, P. E. *et al.* Effects of Plyometric Training and Recovery on Vertical Jump Performance and Anaerobic Power. *J. Strength Cond. Res.* (2003): **17**, 704–709.

14. Tedavi, U. F., Program, R. & Tez, D. Basketbol oyuncularinda vibrasyon eşliğindeki pliometrik eğitimin fiziksel performans üzerine etkileri. (2016).

15. Pereira, A., Costa, A. M., Santos, P., Figueiredo, T. & João, P. V. Training strategy of explosive strength in young female volleyball players. *Med.* (2015): **51**, 126–131.

16. Marques, M. C. & Tıllaar, R. Van Den. Changes is Strength and Power Performance in Elite Senior Female Professional Volleyball Playesr During the In-season:A Case Study. (2008).

17. Krističević, T. Effect of Short High Impact Plyometric Training on Jumping Performance in Female Volleyball Players. (2016).

18. Hrženjak, M., Trajković, N. & Krističević, T. Effects of plyometric training on selected kinematic parameters in female volleyball players | Učinak Pliometrijskog Treninga Na Određene Kinematske Parametre Kod Odbojkašica. *Sport Sci.* (2016).

19. Uluöz, E. 16-22 Yaş Bayan Voleybol Oyuncularında Hipermobilite ve Bazı Antropometrik Özellikler ile Yaralanma Durumları Arasındaki İlişkinin İncelenmesi. (2007).

20. Başandaç, G. Adölesan Voleybol Oyuncularında İlerleyici Gövde Stabilizasyon Eğitiminin Üst Ekstremite Fonksiyonlarına Etkisi. (2014).

21. Akoğlu, A. S. Adölesan Voleybol Oyuncularında Kronik Ayakbileği İnstabilitesinin Denge, Alt Ekstremite Fonksiyonel Hareketleri ve Kalça Kaslarının Kuvvetleri Üzerine Etkisinin İncelenmesi. (2018).

22. Hebert, M. *Thinking Volleyball*. (2013).

23. Jastrzebski, Z., Wnorowski, K., Mikolajewski, R., Jaskulska, E. & Radziminski, L. The Effect of a 6-Week Plyometric Training on Explosive Power in Volleyball Players. *Balt. J. Heal. Phys. Act.* (2014).

24. Challoumas, D., Stavrou, A. & Dimitrakakis, G. The volleyball athlete's shoulder: biomechanical adaptations and injury associations. *Sport. Biomech.* (2017): **16**, 220–237.

25. Lenberg, K. & American Volleyball Coaches Association. *Volleyball skills & drills*. (2006).

26. Reeser, J. C. & Bahr, R. *Handbook of Sports Medicine and Science Volleyball*. (2002).

27. Mackenzie, S., Kortegaard, K., Levangie, M. & Barro, B. Evaluation of two methods of the jump float serve in volleyball. *J. Appl. Biomech.* (2012) : **28**, 579–86.

28. Coleman, J. *The Volleyball Coaching Bible*. **I**, (2002).

29. Gürsoy, V. FIVB 2014 Voleybol Erkekler Dünya Şampiyonasının İstatistiksel Analizi ve Değerlendirilmesi. (2018).

30. Crisfield, D. w. & Monteleona, J. J. *Winning Volleyball for Girls*. (2009).

31. Reeser, J. C., Fleisig, G. S., Bolt, B. & Ruan, M. Upper Limb Biomechanics During the Volleyball Serve and Spike. *Sports Health*. (2010) : **2**, 368–374.

32. Micheli, L. Team Physician Manual. *Team Physician Man.* (2014). doi:10.4324/9780203127773

33. Wilk, K. E., Reinold, M. M. & Andrews, J. R. *The Athlete's Shoulder*. (2009).

34. McGINNIS, P.M. Biomechanics of Sport and Exercise. (2012).

35. Donald A. Chu, P. & Gregory D. Myer, P. *Donald A. Chu, PhD Gregory D. Myer, PhD*. (2013).

36. Hansen, D. & Kennelly, S. *Plyometric Anatomy*. (2017).

37. Tez, S. Ali suluova. (2018).

38. Beyazit, A. Y. *et al.* Bayan voleybolculara uygulanan kor stabilizasyon egzersizlerinin denge ve anaerobik performansa etkisi. (2017).

39. Göveli, H. Farklı Tekrarlı Sprint Testlerinin Performans ve Fizyolojik Yanıtlarının İncelenmesi. (2019).

40. Grgantov, Z., Milić, M. & Katić, R. Identification af explosive power factors as predictors of player quality in young female volleyball players. *Coll. Antropol.* (2013) : **37 Suppl 2**, 61–8.

41. Çimenli, Ö. Farklı Zeminlerde Uygulanan Pliometrik Antrenman Programının Voleybolcularda Sıçrama Kapasitesine Etkisi. (2011).

42. Homoud, A. Relationships between illinois agility test and reaction time in male athletes. *Swedish J. Sci. Res.* (2015) : **2**, 28–33.

43. Çon, M., Akyol, P., Tural, E. & Taşmekteplİgİl, M. Y. Voleybolcuların esneklik ve vücut yağ yüzdesi değerlerinin dikey sıçrama performansına etkisi. *Selçuk Üniversitesi Beden Eğitimi ve Spor Bilim Derg.* (2012) : **14**, 202–207.

44. Leavey, V. J. The Comporative Effects of a Six-Week Balance Training Program,Gluteus Medius Strength Training Program and Combined Balance Training/Gluteus Medius Strength Training Program on Dynamic Postural Control. (2006).

45. Behm, D. G. & Anderson, K. G. The role of instability with resistance training. *J. Strength Cond. Res.* (2006) : **20**, 716–722.

46. Huston, J. L., Sandrey, M. A., Lively, M. W. & Kotsko, K. The Effects of Calf-Muscle Fatigue on Sagittal-Plane Joint-Position Sense in the Ankle. *J. Sport Rehabil.* (2016) : **14**, 168–184.

47. Tot, T. Elit Düzeydeki Erkek Basketbol ve Hentbolcuların Antropometrik Ölçümleri ve Vücut Yağ Oranları ile Denge Düzeyleri Arasındaki İlişkinin Karşılaştırılması. (2009).

48. Sheppard, J. M., Young, W. B., Doyle, T. L. A., Sheppard, T. A. & Newton, R. U. An evaluation of a new test of reactive agility and its relationship to sprint speed and change of direction speed. *J. Sci. Med. Sport* (2006) : **9**, 342–349.

49. Davies, G., L. Riemann, B. & Mankse, R. Clinical Commnetary. Current Concepts of Plyometric Exericse. *Int. J. Sports Phys. Ther.* (2015) : **10**, 768–786.

50. Lloyd, R. S., Oliver, J. L., Hughes, M. G. & Williams, C. A. The effects of 4-weeks of plyometric training on reactive strength index and leg stiffness in male youths. *J. Strength Cond. Res.* (2012) : **26**, 2812–2819.

51. Potach, D. H. Plyometric and speed training. *NSCA's essentials Pers. Train.*

(2004) : 425–444.

52. Rassier, D. E. & Herzog, W. Force Enhancement and Relaxation Rates After Stretch of Activated Muscle Fibers. *2005*

53. Kurokawa, S., Fukunaga, T., Nagano, A. & Fukashiro, S. Interaction between fascicles and tendinous structures during counter movement jumping investigated in vivo. *J. Appl. Physiol.* (2015): **95**, 2306–2314.

54. Chmielewski, T. L., Myer, G. D., Kauffman, D. & Tillman, S. M. Plyometric Exercise in the Rehabilitation of Athletes: Physiological Responses and Clinical Application. *J. Orthop. Sport. Phys. Ther.* (2006): **36**, 308–319.

55. Miller, M. G., Herniman, J. J., Ricard, M. D., Cheatham, C. C. & Michael, T. J. The effects of a 6-week plyometric training program on agility. *J. Sport. Sci. Med.* (2006) : **5**, 459–465.

56. Chimera, N. J., Swanik, K. A., Swanik, C. B. & Straub, S. J. Effects of Plyometric Training on Muscle-Activation Strategies and Performance in Female Athletes. *J. Athl. Train.* (2004):**39**, 24–31.

57. Rimmer, E. Effects of a Plyometrics Intervention Program on AND. *Strength Cond.* (2000):**14**, 295–301.

58. POTTEIGER, J. A. *et al.* Effects of Plyometric Training and Recovery on Vertical Jump Performance and Anaerobic Power. *J. Strength Cond. Res.* (2010): **17**, 704–709.

59. Myer, G. D., Ford, K. R., McLean, S. G. & Hewett, T. E. The effects of plyometric versus dynamic stabilization and balance training on lower extremity biomechanics. *Am. J. Sports Med.* (2006): **34**, 445–455.

60. Özveren, Y. Examining the Effects of Long Term Exercise Training on Some Physical and Physiological Parameters of 12-15 Years Old Children. (2015).

61. Ürer, S. 15-17 Yaş Grubu Erkek Hentbolculara Uygulanan Üst ve Alt Ekstremiteye Yönelik Pliometrik Antrenmanların Dikey Sıçrama Performansına ve Blok Üstü Şut İsabetlilik Oranına Etkisinin Araştırılması. (2013).

62. Mroczek, D. Effects of Volleyball Plyometric İntervention Program on Vertical Jumping Ability in Male Volleyball Players. *2017*

63. Vargas, L. F. Evaluation of Four Vertical Jump Test: Methodology, Reliability, Validity and Accuracy. (2000).

64. Stockbrugger, B. A. & Haennel, R. G. Validity and Reliability of a Medicine Ball. *J. Strength Cond. Res.* (2001): **15**, 431–438.

65. Gjinovci, B., Idrizovic, K., Uljevic, O. & Sekulic, D. Plyometric training improves sprinting, jumping and throwing capacities of high level female volleyball players better than skill-based conditioning. *J. Sport. Sci. Med.* (2017): **16**, 527–535.

66. Hackett, D. A. Predictive ability of the medicine ball chest throw and vertical

jump tests for determining muscular strength and power in adolescents. (2017).

67. Coughlan, G. F., Fullam, K., Delahunt, E., Gissane, C. & Caulfield, B. M. A comparison between performance on selected directions of the star excursion balance test and the Y balance test. *J. Athl. Train.* (2012): **47**, 366–371.

68. Idrizovic, K. *et al.* The Effects of 3-Month Skill-Based and Plyometric Conditioning on Fitness Parameters in Junior Female Volleyball Players. *Pediatr. Exerc. Sci.* (2018): **30**, 353–363.

69. Newton, R. U. & Mcevoy, K. P. Baseball Throwing Velocity: A Comparison of Medicine Ball Training and Weight Training. (1994).

70. Raeder, Christian, Fernandez, jaime F. Effects of Six Weeks of Medicine Ball Training on Throwing Velocity, Throwing Precision and Isokinetic Strength of Shoulder Rotators in Female Handball Players. (2015).

71. Vera-Garcia, F. J., Ruiz-Pérez, I., Barbado, D., Juan-Recio, C. & Mcgill, S. M. Trunk and shoulder EMG and lumbar kinematics of medicine-ball side throw and sie catch and throw. *Eur. J. Hum. Mov.* (2014): **33**, 93–109.

72. Darmiento, A., Galpin, A. J. & Brown, L. E. Vertical jump and power. *Strength Cond. J.* (2012): **34**, 34–43.

73. Park, G. D., Lee, J. C. & Lee, J. The Effect of Low Extremity Plyometric Training on Back Muscle Power of High School Throwing Event Athletes. *J. Phys. Ther. Sci.* (2014): **26**, 161–164.

74. Sozbir, K. Effects of 6-Week Plyometric Training on Vertical Jump Performance and Muscle Activation of Lower Extremity Mu Effects of 6-Week Plyometric Training on Vertical Jump Performance and Muscle Activation of Lower Extremity Muscles/effects-of-6-week-plyometric. *S. Sport. Acad.* (2016): 1–18.

75. Ozbar, N., Ates, S. & Agopyan, A. The effect of 8-week plyometric training on leg power, jump and sprint performance in female soccer players. *J. Strength Cond. Res.* (2014): **28**, 2888–2894.

76. Campıllo, R. R. The Effect of Interday Rest on Adaptation to 6 Weeks of Plyometric Training in Young Soccer Players. (2015).

77. Aksu, A. Adölesanlarda Voleybol Sezobu Süresince Yaralanmaları Önleyici Egzersiz Programının Etkinliğinin Karşılaştırılması. (2014).

78. Ignjatovic, A. m. Effect of 12-week Medicine Ball Training on Muscle Strength and Power in Young Female Handball Players. (2012).

79. Alptekin, A. the Effect of an 8- 8 - Week Plyometric Training Program on. (2013) : **7**, 45–50.

80. Slimani, M., Chamari, K., Miarka, B., Del Vecchio, F. B. & Chéour, F. Effects of Plyometric Training on Physical Fitness in Team Sport Athletes: A Systematic Review. *J. Hum. Kinet.* (2016): **53**, 231–247.

81. Bouteraa, I., Negra, Y., Shephard, R. J. & Chelly, M. S. Effects of combined

balance and plyometric training on athletic performance in female basketball players. *J. Strength Cond. Res.* (2018).

82. Asadı A, Vıllarreal ES, Arazı H The effects of plyometrıc type neuromuscular traınıng on postural control performance of male team basketball players. *The Journal of Strength and Conditioning Research.*(2015).

83. TURGUT, E., COLAKOGLU, F. F., SERBES, P., AKARCESME, C. & BALTACI, G. Effects of 12-week in-season low-intensity plyometric training on dynamic balance of pre-pubertal female volleyball players. *Risk* **26**, 27 (2017).

APPENDİX-A

Araştırma Amaçlı Çalışma İçin Aydınlatılmış Onam Formu

Bu çalışma, kadın voleybol oyuncularında altı haftalık pliometrik egzersizlerin sporcularda koşu, sıçrama, fırlatma ve dinamik denge kapasiteleri üzerine etkilerinin araştırılması amacıyla yapılacaktır. Elde edilen verilerle voleybol sporcularına ve onların ilgili parametrelerinin geliştirilmesine katkı sağlanacak, bu alanda çalışan profesyonellere ve öğrencilere yol gösterici olacaktır. Sizin de ebeveyn olarak kızınızın bu çalışmaya katılmasına izin vermenizi öneriyoruz. Çalışmaya katılım kızınız tarafından gönüllülük esasına dayanır. Kararınızdan önce araştırma hakkında sizi bilgilendirmek istiyoruz. Bu bilgileri okuyup anladıktan sonra araştırmaya katılmalarına izin verirseniz formu imzalayınız.

Çalışma İstanbul Üniversitesi Orman Fakültesi Spor Salonunda yapılacaktır. Eğer kızınızın araştırmaya katılmasını kabul ederseniz, kızınız Fzt. Seda Nur Çimen tarafından fiziksel değerlendirme ve egzersiz programına alınacaktır ve program hakkında kızınıza bilgilendirme yapılacaktır.

Değerlendirme kayıtlarınız kimliğiniz belirtilmeden sağlık alanında öğrenim gören öğrencilerin eğitiminde veya bilimsel nitelikte yayınlarda kullanılabilir. Bunun dışında bu kayıtlar kullanılmayacak ve başkalarına verilmeyecektir. Bu çalışmayı yapabilmek için kızınızın koşu, sıçrama, fırlatma ve denge değerlendirmesi yapılacaktır. Ayrıca kızınızın boy-kilo-yaşı ve yaralanma geçmişi de sorgulanacaktır. Bu değerlendirmeler sporcuların hangi vücut fonksiyonunda zayıflık olduğunu anlamamızda ve o fonksiyona katkı sağlamamızda yol gösterici olacaktır. Daha sonra 6 hafta süresince sporcular haftada 2 gün antrenman öncesi 45-60 dakika boyunca belirlenen egzersiz programını yapacaklardır. Egzersiz program süreci bittikten sonra değerlendirmeler egzersizlerin etkinliğini anlamak açısından tekrar yapılacaktır. Sporcular değerlendirmeler esnasında herhangi bir ağrı veya acı hissetmeyecektir. Kızınızın bu çalışmaya katılması için sizden herhangi bir ücret istenmeyecektir. Kızınız çalışmaya katıldığı için size ek bir ödeme de yapılmayacaktır.

Çalışma kapsamında yapılacak olan değerlendirmeler herhangi bir risk içermemektedir. Çalışmanın devamı sırasında açığa çıkabilecek sorun ve riskler size iletilecektir.

Bu çalışmaya kızınızın katılmasını reddedebilirsiniz. Bu araştırmaya katılmak tamamen isteğe bağlıdır ve reddettiğiniz takdirde kızınızın antrenman programında herhangi bir değişiklik olmayacaktır.

Ebeveynin Beyanı

Sayın Fzt. Seda Nur Çimen tarafından kadın voleybol oyuncularında altı haftalık pliometrik egzersizlerin sporcularda koşu, sıçrama, fırlatma ve dinamik denge kapasiteleri üzerine etkilerinin araştırılması için tıbbi bir araştırma yapılacağı belirtilerek, bu araştırma ile ilgili yukarıdaki bilgiler bana aktarıldı. Bu bilgilerden sonra velisi olduğum kızım böyle bir araştırmaya " gönüllü katılımcı" olarak katılabilir. Eğer kızımın bu araştırmaya katılmasına izin verirsem, bu araştırma sırasında fizyoterapistin kızıma ait bilgilerin gizliliğine büyük bir özen ve saygı ile yaklaşacağına , araştırma

sonuçlarının eğitim ve bilimsel amaçlarla kullanımı sırasında kişisel bilgilerimin ihtimamla korunacağı inanıyorum.

Araştırma için yapılacak harcamalarla ilgili herhangi bir parasal sorumluluk altına girmiyorum ve bana da bir ödeme yapılmayacaktır.

Bana yapılan tüm açıklamaları ayrıntılarıyla anlamış bulunmaktayım. Adı geçen bu araştırmada ebeveyni olduğum kızımın "gönüllü katılımcı" olarak yer alması kararını aldım.

İmzalı bu form kağıdının bir kopyası bana verilecektir.

Gönüllü Katılımcı	**Veli**
Adı, soyadı:	Adı, soyadı:
Adres:	Adres:
Tel:	Tel:
İmza:	İmza:

Çalışmayı yapan fizyoterapist

Adı soyadı: Fzt. Seda Nur ÇİMEN
Adres: Kilyos mahallesi tatlısu caddesi
No:2 Sarıyer /İSTANBUL
Tel: 0506 441 8918

APPENDİX-B

Demografik Bilgiler Formu

1) Adı-Soyadı: .....

Cep Telefon Numarası: .....

Acil Durumlarda Ulaşılacak Kişi Adı Soyadı ve Telefon Numarası:.....

2) Doğum Tarihi: .....

3) Boy Uzunluğu (cm):

4) Vücut Ağırlığı (kg): 5) BMI:

6) Dominant Taraf:

[ ] Sağ

[ ] Sol

7) Pozisyonu:

8) Sigara İçiyor Musunuz?

[ ] Hiç İçmedim

[ ] Sigara İçtim Ama Bıraktım (..... yıl, günde .....)

[ ] Hala İçiyorum (..... yıldır, günde .....)

9) Alkol Kullanıyor Musunuz?

[ ] Evet

( ) Her gün düzenli

( ) Haftada birkaç kez

( ) Ayda birkaç kez

( ) Özel Günlerde

[ ] Hayır

10) Regli olma yaşı/ düzeni:

11) Sürekli kullandığınız bir ilaç var mı?

[ ] Evet (.....)

[ ] Hayır

12) Herhangi bir ameliyat geçirdiniz mi ?

[ ] Evet .....

[ ] Hayır

APPENDIX -C

Curriculum Vitae

Personal Informations

Name	Seda Nur	**Surname**	ÇİMEN
Place of Birth	ISPARTA	**Date of Birth**	20.01.1993
Nationality	TURK	**TR ID Number**	43345387580
E-mail	sedacpt@gmail.com	**Phone number**	05064418918

Education

Degree	**Department**	**The name of the Institution Graduated From**	**Graduation year**
University	Physical Therapy and Rehabilitation	Acıbadem University	2016
High school	-	Şarkikaraağaç Anadolu Öğretmen Lisesi	2011

Languages	**Grades (#)**
English	-

All the grades must be listed if there is more than one (KPDS, ÜDS, TOEFL; EELTS vs),

Work Experience (Sort from present to past)

Position	**Institute**	**Duration (Year - Year)**
Physiotherapist	Sarıyer Municipality Women Volleyball Team	2017-

Computer Skills

Program	**Level**
Microsoft Office Word	Good
Microsoft Office Excel	Average

*Excellent , good, average or basic