T.R.N.C
NEAR EAST UNIVERSITY
INSTITUTE OF HEALTH SCIENCES

EFFECTS OF PLYOMETRIC EXERCISE ON THE SKILL OF HIGH JUMP SHOT AND COMPONENTS OF EXPLOSIVE STRENGTH AND POWER OF UNDER 16 YEARS OLD JUNIOR TEAM HANDBALLERS

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THESIS MASTER

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DEDICATION

TO MY LOVELY DAUGHTER SHALIN AND MY FAMILY FOR GIVING THEIR CONSTANT LOVE, SUPPORT AND ENCOURAGEMENT

Hariwan

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ABSTRACT

Hariwan Abid Taher. Effects of Plyometric Exercise on the Skill of High Jump Shot and Components of Explosive Strength and Power of Under 16 Years Old Junior Team Handballers. Near East University, Institute of Health Sciences, School of physical education and Sports, Master Thesis, Nicosia, 2017.

This research study aims at being acquainted with the effects of plyometric exercise on explosive power, power, and high jump shot of junior team handballers. The sample was 14 handballers representing 70% of *Sumil* youth center as the society in *Dohuk* state at the athletic season of 2015-2016. Explanatory variable is plyometric exercise. The response physical variables are explosive legs power, explosive arms power, legs power, and arms power. The response skillful variable is the high jump shot. The response skill variable was represented by test of high jump shot (HJS). Whereas the response physical variables were represented by vertical jump (VJ), push up (PU), 900 gm. Shoulder shot put (SSP), Right Leg Hoping (RLH), and Left Leg Hoping (LLH). Certain pilot studies have been conducted. Every study had aims different from other one. The pilot studies were of the adopted exercises in the study, conducting a training session, and the physical and skillful tests. The One group Pre-test, Post-test design was adopted between which the plyometric program was executed. The null hypothesis (H_0) was adopted for all variables. There were significant differences between all pre-test and post-test at ($p \leq 0.01$) in HJS (3.0±1.11 and 4.86±1.10, t=4.94), VJ (46.21±4.19 and 52.71±4.36, t=12.22), PU (9.29±1.49 and 11.64±1.22, t=5.69), SSP (17.34±3.04 and 20.36±2.42, t=7.42), RLH (42.64±2.88 and 48.68±3.77, t=6.11), and LLH (41.84±4.69 and 46.31±4.79, t=5.22) and with percentage change of 88.6, 14.25, 27.93, 18.75, 14.33, and 11.03 respectively. This study concluded that the plyometric training had improved the components of the explosive strength and power for legs and arms. It is concluded also that the most improved variables is the arm power.

Key words: plyometric, high jump shot, explosive power, and power.

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation/ symbol	Meaning
ANOVA	: analysis of variance
cm	: centimetre (s)
CMJ	: countermovement jump
CK	: creatine kinase
CSA	: cross sectional area
DOMS	: delayed-onset muscle soreness
DJ	: depth jump
ES	: effect size
GRF	: ground reaction forces
IU	: international unit (s)
$IU\cdot L^{-1}$	: international units per litre
$^{o}\cdot s\text{-}1\ ^{-1}$	: joint angular velocity (degrees per second)
kg	: kilogram (s)
LDH	: lactate dehydrogenase
LPT	: land plyometric training
HRmax	: maximum heart rate (beats per minute)
$V^{\cdot}O2max$	: maximum oxygen consumption (L.min^{-1}, ml.kg^{-1}.min)
m	: metre (s)
$m.s^{-1}$	: metres per second
MHC	: myosin heavy-chain
N	: newtons
1RM	: one repetition maximum
Epos	: positive kinetic energy
PT	: plyometric training
ROM	: range of motion
RFD	: rate of force development
RAST	: running anaerobic sprint test
s	: seconds
SEC	: series elastic component
SJ	: squat jump

SD	: standard deviation
SBJ	: standing broad jump
SSC	: stretch shortening cycle
N·m	: torque (Newton-meters)
VL	: vastus lateralis
VJ	: vertical jump
W	: watts
WT	: weight training
WAnT	: Wingate Anaerobic cycle test

CHAPTER 1

INTRODUCTION

The evolution in the field of scientific research at all levels of the life is necessary, especially at the coaching which is the prop to enhance the skill performance. So, trying to solve athlete problems necessitates using the scientific methodology to achieve the target aims.

Team-handball is an Olympic sport ball game that is characterized by fast pace defensive and offensive action during the game with the objective of the game to score goals. To score goals, the offensive players (6 players and one goalie) attempt to establish an optimal position for the throwing player by fast movements over short distances performing powerful changes in direction (with and without the ball), one-on-one action against defensive players and passing the ball using different offensive tactics (Wagner, Finkenzeller, Würth, & VonDuvillard, 2014).

It is known that the muscular explosive strength and power are important components playing a role in performing the most dependent strength sports games. Improving these two components is a contribution to skill performance depending upon them because it is necessary to avail one or more than a component in which a player needs to perform specifically the game's skills especially those depending greatly upon muscular strength. This concept is manifested obviously in the high jump shot which is characterized by force and speed in addition to the accuracy. Jump height is important for the jump throw in team-handball to reach a high vertical position to throw over the block of the rival defensive players when throwing from backcourt position or to have more time for throwing (an increase in flight time) to mimic or to react to the movements of the goalkeeper (Wagner et al., 2014).

Plyometric actions means to lenghthen and/or pre-stretching of skeletal muscles under loading that allows a more forceful contraction (CON) muscle action. Plyometric actions utilize the stretch-shortening cycle (SSC) and are substantially dependent on loading and the rate of the muscle lengthening during the Eccentric (ECC) phase of contraction (Watkins, 2009).

The SSC consists of the stretch reflex and the muscle's ability to store elastic energy within its series and parallel elastic components.

Plyometric training (PT), either alone or in combination with other typical training modes (e.g. weight training [WT] or electromyo-stimulation), elicits many positive changes in the neural and musculoskeletal systems, muscle function and athletic performance of healthy individuals (Markovic & Mikulic, 2010).

Abdulfatah 1997 indicates that; the plyometric training method contributing to enhance certain physical abilities such as the maximum muscle strength and explosive power as the most important ones. Plyometric exercises program are been shown to have imacts specifically on improving explosive power of the legs, then for trunk and arms (Abdulfatah, 1997, p. 22).

Plyometric training programs have been shown to be effective in adults and pubertal children for improving running speed and jumping ability.

The benefits of Plyometric for improved vertical jumping ability have been well demonstrated in the literature and are widely utilized by athletes and coaches.

Gambetta 1994 and Ballesteros 1989 agreed that exercises of jump and hop performed variously and accompanied with activities in which the muscles contract eccentrically improve the explosive power and time reaction (Ballesteros, 1989; Gambetta, 1994).

Plyometric exercises are distinguished by its ability to increase the motor performance, that is the gained muscular strength of these exercises results in the maximum motor performance of the activity, and increasing the muscle's ability to contract faster and more explosively throughout the range of the movement and with all its speed (Al-Khatib, 1991).

Schiffer 1991 indicated that the main aim of the plyometric is the ability of applying the muscle strength as fast as possible (Schiffer, 2012, p. 247).

Potteiger et al. (1999) showed that a plyometric training (PT) program could bring about significant increases in leg extensor muscle power and whole muscle fiber hypertrophy. (Potteiger et al., 1999). Malisoux et al. (2006a), on the other hand, focused on the contractile properties of single fibers of Vastus lateralis (VL) muscle of recreationally active men. They found that PT induced significant increases in peak force and maximal shortening velocity in the myosin heavy chain (MHC) isoforms Type I, IIa and hybrid IIa/IIx fibers, while peak power increased significantly in all fiber types. (Malisoux, Francaux, Nielens, & Theisen, 2006 a).

Contradictory to the above research, Kyröläinen et al. (2005) found that 15-weeks of maximal-effort PT performed by recreationally active men showed no significant changes in muscle fiber type or size. (Kyröläinen et al., 2005).

1.1 Statement of the Problem

Explosive power and power are prerequisite components which the team handballer needs throughout practicing skills, especially those which requires maximum force as fast as possible. As a practitioner and a coach, I have been found that there is a weakness in the performance of the high jump shot, a skill depending basically upon both the explosive power and power of arms and legs. The importance of the explosive power and power of arms and manifests during shooting, whereas for legs during jumping. So, improving these two components is a prerequisite for team handball game reflected positively in improving and enhancing the high jump shot. Singer 1990 indicates that “the motor skill could not performed without specific physical abilities” (Singer, 1980, p. 221). In addition, the student has been noticed that most of coaches omit plyometric exercise in training sessions. In addition, the focus has shifted to the usage of exercises among children, adolescents, and middle-aged to older adults.in different scrutiny cases; the aspect of the issue which deals with plyometric exercises in these gropus has been the diverse terminology in defining plyometric. Some view plyometric in classic terms as predominantly depth jumping at high levels of intensity (Ratamess, 2012). Some misconceptions concerning plyometric training in youth are that it is unsafe (causes growth plate injuries) and children lack the necessary strength needed to engage in a training program (Ratamess, 2012). The problem of this research study could be summarized in being acquainted with the Effects of plyometric exercise on both the explosive power and the power of the arms and legs of under 16 years old junior team handballers, representatives of the Sumil Youth’s center.

1.2 Hypothesis

1. For high Jump Shot , For explosive power and For power

$H0$: $\mu_d = 0$

The alternative is two-tailed and alpha ≤ 0.05

1.3 Assumptions

This research study assumes that there are:

1. Positive effects of the plyometric exercise upon high Jump Shot of Junior Team Handballers, and
2. Positive Effects of Plyometric Exercise on explosive power and power of the arms and legs of Junior Team Handballers.

1.4 Importance of the Research

The importance of plyometric manifests in urgent utilization of plyometric exercise for team handball to improve the components of the legs and arms explosive power which may result in improving the skill of high jump shot. So, the omission of coaches from this new exercise for junior team handballers requires this research study to be conducted.

1.5 Delimitations

1. The study delimited to 14 male handballers.
2. The study delimited to youth handballers Under 16 Years Old.
3. The study delimited to male handballers of *Sumil* youth center in *Dohuk* state.
4. The study delimited to plyometric training.
5. The study delimited to team handball game as practiced at the athletic season of 2015-2016.
6. The study delimited to physical variables of the explosive legs power, explosive arms power, legs power, and arms power.
7. The study delimited to skillful variable of the high jump shot.

1.6 Limitations

1. All participants were under 16 years old. So, the student may encounter some difficulties concerning dealing with such this ages.

2. This study concentrates upon the variable of plyometric exercise in relation to certain power components and high jump shot. Whilst the research acknowledges that many other variables contribute to the variables of this research. This study has been limited to investigating only plyometric exercise on certain power components and high jump shot.

3. The participants were drawn from players of youth sports center in sport of team handball in the Iraqi Kurdistan Region. Results from this study may not be applicable or transferable to recreational or social levels of this sport.

1.7 Objective of the Study

This research study aims at being acquainted with the:

1. Effects of Plyometric Exercise on high Jump Shot of Junior Team Handballers, and
2. Effects of Plyometric Exercise on explosive power and power of the arms and legs of Junior Team Handballers.

1.8 Definition of the Terms

1. Plyometric training is almost exclusively applied to the extensor muscles of the legs, and consists of a vigorous lengthening of the active extensor muscles (eccentric contraction) immediately followed by a maximal, concentric contraction (Klausen, 1990, p. 48).
2. Power of muscle contraction is a measure of the total amount of work that the muscle performs in a unit period of time. Power is therefore determined not only by the strength of muscle contraction but also by its distance of contraction and the number of times that it contracts each minute (Hall & Guyton, 2006, p. 1056).

CHAPTER 2

LITERATURE REVIEW

2.1 Body literature

2.1.1 Brief information of Team Handball

Handball (also known as team handball or Olympic handball) (Schrodt, 2011). Is a team sport in which two teams of seven players each (six outfield players and a goalkeeper) pass a ball using their hands with the aim of throwing it into the goal of the other team. A standard match consists of two periods of 30 minutes, and the team that scores more goals wins ("Handball World Championship in PARIS," n.d.).

Modern handball is played on a court 40 by 20 meters, with a goal in the middle of each end. The goals are surrounded by a 6-meter zone where only the defending goalkeeper is allowed; goals must be scored by throwing the ball from outside the zone or while "jumping" into it. The sport is usually played indoors. The game is fast and high-scoring: professional teams now typically score between 20 and 35 goals each, though lower scores were not uncommon until a few decades ago. Body contact is permitted by the defenders trying to stop the attackers from approaching the goal (Schrodt, 2011).

A standard match for all teams of at least age 16 has two 30-minute halves with a 10- to 15-minute halftime break. At half-time, teams switch sides of the court as well as benches. For youths the length of the halves is reduced 25 minutes at ages 12 to 15, and 20 minutes at ages 8 to 11; though national federations of some countries may differ in their implementation from the official guidelines (The official Handball rules, n.d.).

If a decision must be reached in a particular match (e.g., in a tournament) and it ends in a draw after regular time, there are at maximum two overtimes, each consisting of two straight 5-minute periods with a one-minute break in between. Should these not decide the game either, the winning team is determined in a penalty shootout (best-of-five rounds; if still tied, extra rounds afterwards until won by one team) (Schrodt, 2011).

The referees may call timeout according to their sole discretion; typical reasons are injuries, suspensions, or court cleaning. Penalty throws should trigger a timeout only for lengthy delays, such as a change of the goalkeeper (Schrodt, 2011).

Since 2012, teams can call 3 team timeouts per game (up to two per half), which last one minute each. This right may only be invoked by team in ball possession. Team representatives must show a green card marked with a black T on the timekeeper's desk. The timekeeper then immediately interrupts the game by sounding an acoustic signal and stops the time. Before that, it was one per half. For purpose of calling timeouts, overtime and shootouts are extensions of the second half (Schrodt, 2011).

The goalkeeper and the six main outfield players are situated at the following posts according to the attacking and defending positions: Right Wing, Right Back, Center Back, Left Back, Left Wing, Pivot, and Goalkeeper (Juhász et al., 2015).

Techniques of scoring a goal include Stride Jump Shot and high jump shot

2.1.2 High (Vertical) jump shot

Vertical jump shot is an especially distinguished technical element, since it is one of the most effective ways of shooting. Its technique is the following: gaining velocity, jump up, work in the air, shot, and landing. Velocity can be gained by running steps, feints (feinting a start, feinting direction change) and skipping in. Phases with and without ball can be distinguished. The most difficult way of vertical jump shot is jump from one step. The most frequent one is vertical jump from two steps. An attacker jumps from three steps when he is far from the goal or he has a possibility to complete the shot farther in width from the defender. In case of classical vertical jump shot jump is performed from the leg opposite the shooting hand. The jump insures the vertical position for the shooter from which he can shoot successfully at the goal above or near the defender. The work of the jumping leg is much supported by the swinging leg, which means swinging the knee up or transversally forward-sidelong. Swing the knee can give impulse to the jump as long as the jumping leg is on the ground. The swinging knee is involved in the last phase of the jump and stops in the air, the thigh is horizontal. The ball is prepared at the same time as the knee is swung, which means the trunk is turned towards the throwing arm, which is connected to different possibilities of ball preparations, that is the movement of the ball. The arm opposite the shooting hand is swung forward-up in the jump phase to help the jump, then the player keeps it in front of him slightly bent until the upper deadlock of the jump.

Preparation of the ball can happen long in big arc, with lift-out in small arc and short straight. Preparation in big arc can only be possible in case velocity is gained in several steps and at those players whose palm is big, so he can hold the ball tight. When speeding up the ball on long arc there is the danger that it slips out of the hand of the player at the lower deadlock. The arc takes a whole circle, the end point of the preparation is the same as the end point of the upper throw. In case of small arc preparation the player must hurry to take the ball to a right throwing position in a right time. This sequence of movements is different from big arc in the way that here the arm is led not by the route of the ball, but by lifting the elbow backward and upward. The twist of the trunk and the work of the passive arm is the same as in big arc. The essence of short preparation is that the player quickly lifts the ball held at chest height above the shoulder of the shooting arm at the shortest way (Juhász et al., 2015).

2.1.3 Muscular strength and power

2.1.3.1 Muscular strength and power as fitness components

Fitness components may be classified in two ways: “health-related and skill-related fitness components” (Fahey, Insel, & Roth, 2005). Health-related fitness components are are designated to improve health, wellness, and quality of life. Like these Improvements could support physical performance. Muscule strength, muscule endurance, cardiovascular endurance, flexibility, and body composition are included in Health-related components. power, speed, agility, balance and coordination, and reaction time could be included in Skill-related components of fitness. All components above are critical to sports performance and to perform daily living activities. Skill-related components could be developed in a different of method such as training with resistance, sprint, interval, agility and plyometric, and through sport- related training.

2.1.3.2 Muscular Strength

Muscular strength could be defined as “the maximal amount of force one can generate during a specific movement pattern at a specified velocity of contraction” (Knuttgen & Kraemer, 1987).

Abemethy, Wilson, & Logan, 1995 defines strength as thee peak force (in newton, N) or torque (in newton-meters, Nm) developed during a maximal voluntary muscle contraction(s) under a given set of conditions influenced by posture, pattern and velocity of movement (Abemethy, Wilson, & Logan, 1995). For team handball where there is a variation of tasks, the velocity of movement and loads imposed upon player vary within and between the tasks. A handballer may experience various muscle loads throughout a game such as isometric, isotonic, plyometric, slow and fast movement velocities. Because the varied application of strength and power demands in team handball, it is important that handballer has optimized levels of force, torque, speed and power to product ‘just the actual amount at the real time’ of these motor abilities.

Carvalho, etal, 2014 examined the effects of a 12-week strength training program combined with specific plyometric exercises on body composition, vertical jump (VJ) height and strength development of lower limbs in Twelve elite male handball players(age: 21.6 ± 1.73). It was found that there was an increase in squat jump (SJ), counter movement jump (CMJ) and 40 consecutive jumps after the training period. After the applied protocol, peak torque increased in lower limb extension and flexion in the majority of the movements assessed at 90ºs-1. Consequently, it is possible to conclude that combining general strength-training with plyometric exercises can increase lower limb strength and improve VJ performance(Carvalho, Mourão, & Abade, 2014).

Chelly etal, 2014 replaced a part of the normal in-season regimen of top-level adolescent handball players (23 men, age: 17.4 ± 0.5 years) by an 8-week biweekly course of lower and upper limb plyometric training. It was found that the experimental group had improved significantly in force-velocity ergometer tests for upper and lower limbs, SJ squat jump (height $p < 0.01$; force $p \leq 0.05$), countermovement jump CMJ (height $p < 0.01$; force $p < 0.01$ and relative power $p \leq 0.05$), and sprint velocities ($p < 0.001$ for first step, first 5 m , and 25-30 m). Also it was found that there were increases in leg and thigh muscle volumes ($p < 0.001$). it was concluded that introduction of biweekly plyometric training into the standard regimen improved components important to handball performance, particularly explosive actions, such as sprinting, jumping, and ball throwing velocity (Chelly, Hermassi, Aouadi, & Shephard, 2014).

Because force is a vector quantity, strength will have a magnitude and direction. The magnitude of strength output can range from 0 to 100% and the muscles involved determine the direction of force application. It is important to understand that strength can be "applied" using different muscle actions. Muscle Action could be refered as the muscular contraction type.

Strength is exhibited when muscles act to produce force. Muscle action can take different four different Actions:

- isometric (ISOM) muscle action includes force development with no change in joint angle or muscle length.
- concentric (CON) muscle action includes muscle shortening and is defined sometimes as a positive component of each repetition.
- eccentric (ECC) muscle action ivcludes muscle lengthening, and is defined sometimes as a negative component of each repetition. ECC muscle actions generates higher levels of force, are very helpful to muscle growth, and make an athlete more susceptible to muscle injury and soreness (Ratamess, 2012).
- Plyometric - in which a concentric action is immediately preceded by an eccentric action, thus taking advantage of a stretch-shortening cycle.

Muscular strength is multidimensional and rely on some factors other than muscle actions such as contraction velocity, muscle group and length, joint angle, and other physiological and biomechanical factors regarding the muscul, nervous, metabolic, endocrine, and skeletal systems.

In, the production of strength relay ordinarlly on major factors such as th following:

- Structural Factors
    - The cross-sectional area of a muscle
    - The density of muscle fibers per unit cross-sectional area
    - The efficiency of mechanical leverage across a joint
- Functional Factors
    - The number of muscle fibers contracting concurrently
    - The rate of contraction of muscle fibers
    - The efficiency of firing synchronizing of muscle fibers
    - The conduction velocity in the nerve fibers
    - The degree of inhibition of muscle fibers which do not cause to the movement
    - The size of large diameter muscle fibers active
    - The efficiency of coordination among various types of muscle fibers
    - The efficiency of the different stretch reflexes in regulating muscle tension
    - The excitation threshold of the nerve fibers providing the muscles
    - The initial length of the muscles before contraction

2.1.3.3 Function of Velocity on Muscle Force Production

The velocity of muscle contraction plays an essential role in the extent to which the force could be produced. Figure 2.4 shows the relationship of force- velocity. Skeletal muscle fibers produce force to be compatible with an external loading, i.e., increasing velocity of shortening throughout light loads and decreasing velocity of shortening with greater loads. For concentric actions of the muscle, greatest force could be produced at slower contraction velocities whereas less force could be produced at faster contraction velocities. Thus, force increases as velocity slows and decreases as velocity increases. For example, a (1RM) bench press is carried out at a slow velocity. Despite the fact that the individual supplies his force as much as possible, the overall net velocity stills slow due to the high external load. Peak isometric force take places at 0 m/s_{-1} (no movement) that is greater than peak concentric force. The force inequality may be related to the number of muscle cross-bridges formed once again. Actin filaments slide quickly at rapid velocities, so that it is more difficult for myosin to constitute cross-bridges with actin.

Having the rate of a cross-bridge cycling increased, less cross-bridges stay intact at any given time. However, formation of a cross-bridge could be supported at slower velocities and throughout isometric actions where the rate of cross-bridge cycling is low. This leads to production a greater force.

2.1.3.4 Velocity of eccentric movements

Contradictory, muscle force could be increased as velocity increases during eccentric actions. Loading greater than the peak isometric force level may cause muscle fibers to lengthen. Additional loading could increase the lengthening velocity. Thus, "muscle force increases as lengthening velocity increases because the fibers are contracting as they are lengthening and greater force is present during eccentric actions" (Ratamess, 2012).

2.1.3.5 Influence of Muscle Length

The length of Skeletal muscle has an important effect on force production. This effect has been termed as the muscle length-tension relationship. Figures 2.1 and 2.2 show the muscle length-tension relationship. This parabolic curve shows that greatest tension is produced in the middle slightly past resting muscle length. This length of the sarcomere, the functional component of a muscle fiber, shows the optimal interaction of the highest number of musclar contraction proteins (actin and myosin). When investigating overall musclar tension, both active and passive elements contribute, with active elements contributing extremely from short to moderate lengths and passive elements contributing extremely at moderate to longer lengths. At shorter muscle lengths, there is overlap of the actin filaments, which decreases actin and myosin interaction. Because muscle tension is relative to the number of cross-bridges shaped, shorter lengths geometrically pose a difficulty decreasing active muscle tension. Hypothetically, at longer muscle lengths a similar event may take place where cross-bridge formation is decreased.

In this sitiuation, myosin filaments could not arrive as many actin filaments. However, the passive neuromuscular elements require a consideration, as shown in Figure 2.2, where at long lengths they highly cause rebounding muscle tension. Tension built up in the tendon, cross-bridges, and structural proteins (series elastic component) and from the muscle fascia (parallel elastic component) increases." Although cross-bridge interaction is minimal at longer muscle lengths, tension rebounds mostly due to resistance to stretch from tendons and skeletal muscle fascia along with some tension produced within the contractile and structural proteins" (Ratamess, 2012).

2.1.3.6 Stretch-Shortening Cycle

Human movement that starts with a counter-movement leads to a more forceful action when the movement is in opposite direction. An eccentric muscle action that comes before a concentric action leads to a more powerful concentric action. This event is termed as the stretch-shortening cycle (SSC) and enables the athlete to develop larger force and power outputs. The SSC includes the stretch reflex and the muscle ability of storing the elastic energy in its series and parallel elastic components. Of the two primary mechanisms, storage of elastic energy cause the SSC up to ∼70%. The stretch reflex is launched by a particular sense receptor, the muscle spindle, which react to both the size and rate of change in muscle length. The result is the SSC can improve performance by 15%–20% as an average (Newton, 2008). The SSC is most distinguished in fast-twitch (FT) muscle fibers (as greater elastic energy storage is accompanied with faster FT fiber motion) and could be trained highly by plyometric, sprint, agility, and resistance training.

Critical to SSC action is that the concentric action follows right away. Any stop between the eccentric and concentric phases (or begining an action without a counter-movement) may lead to weakend performance. Elastic energy stored skeletal muscle could be losted as a heat energy. Although elastic energy improve performance, heat energy supply a little to no ergogenic effects.

Subsequently, force and power cuold be decresed relative to the length of the stopping between muscle actions. "This has been taken place throughout resistance exercise" (Wilson, Elliot, & Wood, 1991). Maximizing SSC activity involves performing ballistic muscular actions with minimal time lapse between eccentric and concentric muscle actions. “Lastly, SSC activity is decreased following periods of high-intensity static stretching” (Power, Behm, Cahill, Carroll, & Young, 2004). Muscular stiffness improves SSC function; so, static stretching that lessens stiffness can reduce force and power production.

2.1.3.7 Power

Power is the rate of executing a work. Since power is the product of force and velocity, there is a strength component to power development (strength at low-to high velocities of contraction). The optimal expression of muscular power is dependent on the proper exercise technique. Somtimes the terms of power and strength are misunderstood and interchangeably used. Power has a time component; so, if two athletes have the same maximal strength, the one who manifest his strength at a higher rate (higher velocity or shorter period of time) will have a distinguished advantage in performance of anaerobic sports. In addition, power could be defined in terms of strength. For example, terms such as speed strength and acceleration strength could be utilized to describe the development of force across a range of velocities. Starting strength is a term used to define production of power production during the initial potion of a movement. Rate of force development, defines power output throughout an explosive exercise excercise, e.g., assessed by the time required to arrive a threshold level of force or the amount of force produced per second (Ratamess, 2012).

The velocity component of the power equation implies that high velocities of the muscle contraction are necessary. So, power development is multidimensional, including enhancement of both force and velocity components. “Muscle power may be enhanced by resistant training, speed, agility, and plyometric training, and through sport- specific practice or conditioning” (Ratamess, 2012).

2.1.3.8 Speed strength and strengthspeed

The preceding force–velocity curves supply a functional ways to mark the deferent between the varoius strength- specific fitness components. It could simply refer to speed strength, but this hide the fact that some ‘speed strength’ sports need a greater focus on speed, wheras other spors emphasis more on strength. Force velocity curve shows this apparently, which shows various strength- specific fitness components ranged between the extremes defined by V = 0 (isometric strength) and V = very large (explosive strength).

Investigating the force–velocity curve helps identifying five different strength-specific component: “isometric strength at zero velocity; quasi-isometric strength at very low velocities; strength-speed at low velocities; speed-strength at intermediate velocities; and explosive strength at high velocity” (Siff, 2000).

The distinction between strengthspeed and speed-trength has a specific particular significance in designing conditioning programs for particular sports. The former relates to training where speed improvement is necessary, but strength is more significant, whereas the latter relates to training where speed improvment against resistance is necessary, but strength gaining is slightly less significant. Within the competitive environment, speed strength and strength speed sports could be classified into the following categories:

- “Cyclical, maximum-power, short-duration running, swimming and cycling.
- Maximum power output sprint activities with jumping or negotiating obstacles (e.g. hurdles).
- Maximum power output activities against heavy loads (e.g. weightlifting).
- Maximum power output activities involving the throwing of implements (e.g. shot put, hammer, and javelin).
- Jumping activities.
- Jumping activities involving an implement (pole vault)” (Siff, 2000).

Physically, terms of speed strength and strength speed are interchangeable with high power (the rate of excuting a work). This quantity is what obviously mark the deferent between speed strength and strength speed events from all other kinds of sports, they both generate a very high power in comparison with their longer duration, lower intensity counterparts.

Finally, to analyze speed strength and strength speed event, an attention should go to release of stored elastic energy from non-contraction tissues after stretching by preceding eccentric contraction contractile musclar processes, since some of these implied freguently in types of rapid action of the contaction musclar process. The effect of the myotatic stretch reflex and other neural events in making powerful involuntary muscle contraction easy should also be considered. It is necessary to note that the Hill and Perrine–Edgerton curves do not utilized in actions recruiting strongly the stretch reflex or involve releasing the stored elastic energy.

2.1.3.9 Specific forms of strength expression

Every sports movement exhibits some essential kinds of strength exhibitions at various phases of the movement, specifically starting strength, acceleration strength, explosive strength, absolute strength, and strength-endurance. These strength kinds could be defined by investigating the gualaties of this graph and extending its range by drawing some of the most significant variables, such as slope (see Fig. 1).

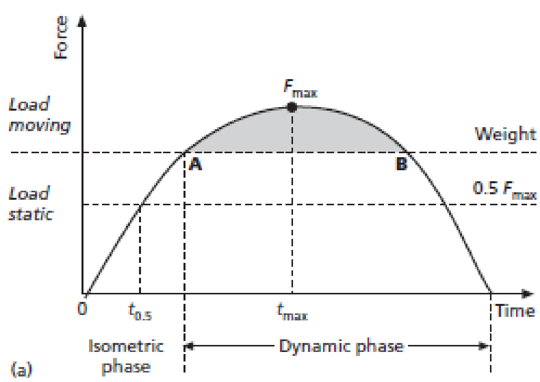

Figure 1. Force–time curve.
This figure illustrates a procedure to determine explosive, starting and acceleration strength in lifting a weight. W is the weight being overcome by the force F (t). “Movement takes place only when the force goes beyond the weight W of the object, namely over the shaded portion of the curve” (Siff & Verkhoshansky, 1999).

Reley on the main coordination structure of the motor activity, muscule strength obtains a specificity which be more apparent as the mastery level of of an athlete improves.

Absolute strength is defined as maximum involuntary strength, while speed strength (power) describes the ability of quick performing an unloaded movement or a movement against a relatively small external resistance.

Explosive strength describes the ability to generate maximal force in a minimal time.

Analysis of the F(t) curve of explosive force shows three further qualaties of the movement,:

• the maximum strength of the muscles involved (Fmax);

• the starting strength, or ability of the muscles to develop force during the phase just preceding occurring of the external movement (this always occurs under isometric sitiuations); and

• the acceleration strength, or ability over time to produce quickly maximal external force while developing muscle tension isometrically or during the primary phasces of a dynamic contraction.

Explosive strength is most exhibited in sports movements when the contraction of the active muscles in the fundamental phases of the exercise is preceded by mechanical stretching. In this moment, the switch from stretching to active contraction utilizes the elastic energy of the stretch to enlarge the power of the following contraction. This particular quality of muscle is termed its reactive ability.

Strength endurance describes the ability to efficiently sustain muscular functioning for a long period. This could be referred in sport as the ability to produce a certain minimum force for a long time. There are various kinds of muscular functioning connected with this ability, such as holding a specified position or posture (static strength endurance) maintaining cyclic work of various intensities (dynamic strength endurance) or repetitively performing explosive effort (explosive strength endurance) (Siff, 2000).

Classification of strength capabilities into four separate kinds (absolute strength, speed strength, explosive strength and strength endurance), as explained above, can be limited in some ways, since all of them are related one to other in their production and development, in spite of their inherent specificity. They are seldom, if ever, manifested apart, but are the components of any movement.

2.1.3.10 Speed, speed strength and quickness

The patterns of athletic movement reflect the compound and non-linear sum of many functions of the body, especially the rate of starting the movement or increasing the speed at any phase of the movement. Regardless of sprinting or throwing the sport is, all movements depends upon speed of execution. However, this of course does not mean that a specific speed component is the onley basis to success. In the basic forms, “speed is displayed in simple, unloaded single-joint movements and involves relatively independent factors such as reaction time, individual movement time, ability to initiate a movement quickly and maximum frequency of movement” (Siff, 2000).

However, developing speed in simple movments does not necessarily improve the speed of ovivously related compound movements. This is due to the absence correlation among fundamental forms of speed activity and the speed of action in cyclic sport locomotion. “This is because far more complex neurophysiological control mechanisms and their associated metabolic processes underlie speed in cyclic movements. For example, many motor qualities determine sprinting ability, such as explosive strength, acceleration ability in the start, the development and maintenance of maximum movement speed, and resistance to fatigue” (Verkhoshansky, 1977).

“Speed in sport movements comes primarily from strength and specific types of endurance, although this does not exclude the role of quickness (the ability to initiate movement rapidly from a static state without pre-stretch), which is just as inherent as strength and endurance, but is displayed fully only when the external resistance of the movement does not exceed 15% of maximal strength” (Verkhoshansky, 1977).

“Speed of movement is associated largely with the fast and slow fiber composition of the muscles, which possess different contractile and metabolic qualities” (Komi, 1979). “It has been fairly well established that athletes who possess a large proportion of fast fibers in their muscles, under equal conditions, display greater movement speed and ability to generate force” (Komi, 1979).

In addition, “excitability of the nervous system is a factor which governs individual speed production, as it has been shown that people with high excitability of the nervous system are distinguished by great speed of movement” (Verkhoshansky, 1977). Speed obivously has an upper limit that is determined greatly by genetics, and absence improving in sprint events is not due to the existence of some 'speed barrier', but to limitations imposed by an individual's speed potential. In addition, all factors affecting speed of action have not been recognized yet and further studies may make advances in this field.

It is necessary to indicate that maximum speed could be produced only if the corresponding action receives adequate energy for its execution. As a result, in activities requiring the athlete to attain high speeds and oppose large resistance in addition to resist fatigue, it is important to investigate not only the improving of speed, but also those physiological mechanisms included, such as the contractile potential of the muscles and the underlying metabolic processes. "In situations where speed of movement does not require great strength or endurance, it should not be impaired by training with large volumes of redundant work, especially when one notes the relatively low training volumes which are used by top-level sprinters" (Siff, 2000).

It is concluded from above that quickness and speed of action are two of the most critical independent components in all sports, because, even in obviously less dynamic sports there are always certain phases where efficiency of speed production can marke the difference between success and failure.

Quickness is a general component of the central nervous system, being exhibited most powerfully during reflexive motor reactions and production of the simplest unloaded movements. Genetic factors determines The quickness of an individual in any form in which could be displayed so that its improving is limited. However, reflexes could be change as originally was shown by Pavlov. "Indeed, the ability to condition different reflexes and enhance the efficiency of feedforward mechanisms in the brain are integral components of motor proficiency in sport" (Siff & Verkhoshansky, 1999).

Speed of action is a function of quickness, reactive ability, strength, endurance and skill to efficiently coordinate movements in response to external conditions under which the motor task is to be performed (Fig. 2). Compared with quickness, there is far greater potential to enhance speed of movement.

It is important to recognize that various movements in sport depend upon the same major motor apparatus and processes. The body does not use narrow, purpose-specific mechanisms to meet a motor demand, such as the production of speed, strength or endurance, but utilizes a multi-purpose system which could control a enormous arrangements for different actions. This noteably ability to adapt to unusual environmental conditions is due to the functional improvement of these systems which encounter excessive efforts, such those in sport.

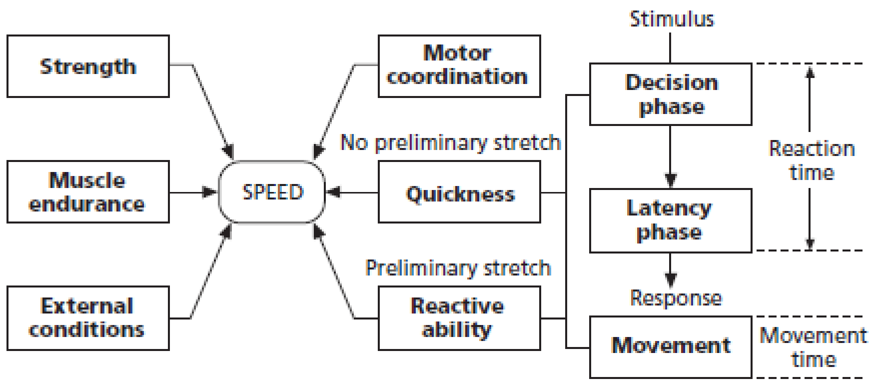

Figure 2. "Factors which determine speed of movement.
A marked decision phase occurs only if the action is cognitive rather than reflexive" (Siff, 2000).

So, any improvement in the work capacity of an athlete is associated with the functional specificity of all bodily systems in a way which generate a high degree of strength, speed or endurance.

2.1.3.11 Specificity in training

Training for improving strength and power is not simple at all because strength training displays bbvious specificity in many respects: all forms of strength training are not the same and produce significantly various effects on neuromuscular action.

the exercise and the mode in which the exercise is excuted adjudt the neuromuscular system,. All exercise included information processing in the central nervous and neuromuscular systems, so that all training should be considered as a way in which the body's highly compound computing systems are programmed and utilized in solving of motor tasks (among its many other roles).

Strength training must imitate the sporting actions as closely as possible in aspects of pattern of movement, velocity, force–time curve, type of muscle contraction and so forth. Literature made a "superiority of the specificity principle in the following respects: type of muscle contraction; movement pattern; region of movement; velocity of movement; force of contraction; muscle fiber recruitment; metabolism; biochemical adaptation; flexibility; and fatigue" (Siff, 2000).

Specificity and simulation munst not be confused in training. Specificity training is to enhance in a extremely specific manner the manifestation of all the above factors in a sport. Simulation of a sport action is small additional resistance over the full range of movement or with greater resistance over a restricted part of the movement range. Simulation of a movement with significant resistance is not recommended because it can confuse the neuromuscular programs which determine the specificity of the factors mentioned above.

Utilizing performances or loads very close to those in a specific sport in simulation training will usually make alterations in the gravity center, moments of inertia, rotation center of, center of percussion and mechanical stiffness of the system which change the neuromuscular skills required in the sport.

Physical fitness for a sport needs improving various kinds of strength and endurance, a process that initiates in the neuromuscular system. It rely upon hypertrophy of the muscles, improved intramuscular and intermuscular control, and an increase in metabolic competence. Improving muscular potential could increase absolute strength, explosive power and endurance.

Strength could be improved by increasing functioning of the intramuscular processes via increasing the number of motor units included in musclar contraction, via increasing motor neurone impulse frequency and via enhancing firing synchronization. This is coordinated with increasing excitation intensity of the motor neurones from the neurones and receptors of the upper motor levels (the motor cortex, subcortical motor centers and intermediate neurones of the spinal cortex).

Maximum strength could be increased basicly by involving large motor units in a contraction, whereas endurance work needs activation of small units. In the latter case it could be altering the activity of different units, which make work-capacity to be sustained for longer. Explosive strength is displayed by a quick increase in muscle tension and is related extermly to the nature of the nervous excitation of the muscles. It is mainly the initial impulse frequency of the motor neurones and their degree of synchronization that generate quicker mobilization of the motor units.

As mentioned above, the force–time curve of explosive effort is charactrized by qualities of the neuromuscular system such as absolute strength, starting strength and acceleration strength. “The validity of isolating starting-strength and acceleration-strength has been corroborated by electromyographic research, which reveals differences in their neuromotor patterns, the recruitment of motor units and the firing frequency of the motor neurones during the production of explosive force” (Verkhoshansky, 1977). This confirms the hypothesis that “starting strength is to a certain extent determined by the innate qualities of the neuromuscular apparatus, particularly the ratio of fast- to slow-twitch fibers in the muscles” (Viitasalo & Komi, 1978).

Specificity of the neuromuscular system to develop absolute, starting and acceleration strength is determined basically by the size of the external load overcome. So, as the moment of inertia of a rotating mass increases and resists movement, the nature of explosive strength shows that the roles of starting strength and speed of movement decrease, while the roles of absolute strength and acceleration strength increase. So, the greater the external load, the larger the role of absolute strength.

2.1.4 Plyometric

Interest in plyometric training has greatly enlarged since the 1970s. Since it was a new training method, scientists and coaches start to attribute the performance improvment to plyometric training. “The benefits of plyometric training in enhancing explosive power performance soon were seen by coaches all over the world and became a staple in the training of strength/power athletes into modern day” (Ratamess, 2012).

Plyometric actions could be referred as the lengthening or pre-stretching of skeletal muscles under resistance allowing a further poerful contraction (CON) muscular action. Plyometric actions uses the (SSC) and are significantly dependent upon loading and the rate of lengthening during the (ECC) phase of contraction. Plyometrics actions not only consist high intensity movements such as depth jumps but consist also simple activities such as hopping, jogging, walking, and multi-directional movements where the stretch shortening cycle SSC increases mechanical efficiency. The concept of plyometric nowadays consists of a range of exercises from low to high intensity instead of the old concept which included high-intensity exercises entirely. This could be explained by the fact that some plyometric drills that considered low or moderate intensity, they are still excuted explosively but consist of less Eccentric ECC loading. Thus, all plyometric exercises “allow an athlete to reach maximal strength and power in the shortest period of time”(Chu, 1998).

“Plyometric exercises are classified based on the intensity level. Maximal plyometric involve ultrahigh-intense muscular contractions and typically comprise depth jumps and variations” (Verkhoshansky & Siff, 2009). “Submaximal plyometric involve low- and moderate-intensity drills that comprise most exercises other than depth jumps” (Verkhoshansky & Siff, 2009). In addition, “plyometric exercises can be impact-oriented (jumps, hops, skips, plyo push-ups) where the reversible action is stimulated by contact with the ground or object, or nonimpact- oriented (strikes, thrusts, throws, passes, and tosses without prior catching of the ball) where the drill is an open chain, i.e., the ECC and CON phases are not augmented by direct contact with the ground or object” (Verkhoshansky & Siff, 2009).

2.1.4.1 Physiology of Plyometric Exercise

Plyometric exercise stimulates SSC activity. The counter-movement initiates the stretch reflex that leads to an ECC muscular action that precedes a brief ISOM phase and subsequent CON muscle action. The ECC phase, plus prior delay seen between musclar activation via neural action potentials and muscular contraction [electromechanical delay] is termed as the amortization phase. The length of the isometric (ISOM) phase between ECC and CON actions is termed as coupling time. The subsequent CON muscular action is augmented by the stretch reflex and the release of elastic energy. The muscle tendon complex play a role like a rubber band when it is stretched. It has elastic potential and the ability to rapidly store and release elastic energy. Elastic energy stored basically within the series elastic component (tendon, actin, myosin, and structural proteins) during an ECC muscle action augments muscle force and power during the CON phase when it follows right away. Maximal force and power could be manifested when the ISOM coupling time is minimal.

"It has been recommended that coupling time be less than 0.15 second, especially in athletes who possess higher percentages of fast-twitch (FT) muscle fibers" (Verkhoshansky & Siff, 2009). Thus, minimizing the length of the amortization phase and coupling time is critical to develop maximal power. Energy could change its form and elastic energy is wasted as coupling time increases (elastic energy spread out into heat energy in proportion to the length of the coupling phase). Elastic energy improves muscle performance whereas heat energy has minimal effects.

Utilizing elastic energy could be maximized when the CON phase follows right away the ECC phase. The second major contributor to the SSC is the stretch reflex. Muscular spindles located within skeletal muscular fibers detect the size and rate of length changes. The response is to send action potentials to the central nervous system where the agonist muscle's force production is improved while the antagonist muscles relax. "In combination, both mechanisms contribute to SSC function although storage/use of elastic energy contributes to a greater extent (by up to 70%). With training, more energy can be stored and utilized as muscle force increases" (Zatsiorsky & Kraemer, 2006). Muscular power and rate of force development increase. This is critical to sport performance where force must be maximized in short time periods. Plyometric training is built to train the SSC by neural adaptations, reflex potentiation, and improved elastic potential of skeletal muscles. The selective recruitment of FT motor units is benificial for acute power performance. Lastly, “the FT units stay facilitated as activities performed after explosive plyometric exercises are enhanced to a greater extent” (Masamoto, Larson, Gates, & Faigenbaum, 2003).

Peak performance in sport requires technical skill and power, where success is dependent upon the speed at which muscular force or power can be generated (Voight & Tippett, 2004). Power combines strength and speed (Radcliffe & Farentions, 1999). It can be improved by increasing the amount of work or force that is produced by the muscle or by decreasing the amount of time required to produce force. The amount of time required to produce muscular force is an important variable for increasing power output. The training method which combines speed of movement with strength is plyometric (Voight & Tippett, 2004).

According to Coetzee 2007, plyometric training (PT) or the combination of PT with a sport-specific training program, have acute and chronic training responses. The acute effects of plyometric programs include a significant increase in the 1RM leg strength and the delayed onset of muscle soreness. Chronic improvements include increases in explosive power, flight time and maximal isotonic and isometric leg muscle strength, average leg muscle endurance, isokinetic peak torque of the legs and shoulder, range of ankle motion, speed and frequency of muscle stimulation. PT programs also seem to significantly decrease ground contact time during sprinting activities and the amortization time during execution of plyometric exercises (Coetzee, 2007).

2.1.4.2 Phases of Plyometric activity

The following phases of action between initiation and finishing the succession of events characterize the Plyometric activity (Fig. 3).

“An initial momentum phase during which a body or part of a body is moving since of kinetic energy (KE) it has accumulated from a preceding action” (Siff, 2000).

“An electromechanical delay phase, which occurs when some event, such as contact with a surface, prevents a limb from moving further and stumulate the muscles to contract" (Siff, 2000). "This delay refers to the time elapsing between the onset of the action potential in the motor nerves and the onset of the muscle contraction. Depending on joint action, this delay varies in magnitude from about 20 to 60 ms" (Cavanagh & Komi, 1979; Norman & Komi, 1979).

"An amortization phase when the KE produces a powerful myotatic stretch reflex which result in eccentric muscular contraction accompanied by explosive isometric contraction and stretching of connective tissues of the muscle complex. The explosive isometric phase between the termination of the eccentric action and initiation of the concentric action lasts for a period called as the coupling time (Fig. 3) which will be discussed shortly in greater detail" (Siff, 2000).

"A rebound phase involving the release of elastic energy from connective tissue, together with the involuntary concentric muscle contraction evoked by the myotatic stretch reflex and augmented nervous processes. This phase sometimes may include a timed contribution added by voluntary concentric contraction. The relative contributions to the process by elastic energy and nervous processes is currently a matter of vigorous controversy. e.g. see" (van Ingen Schenau, Bobbert, & de Haan, 1997).

"A final momentum phase which occurs after the concentric contraction is complete and the body or limb concerned continues to move by means including the kinetic energy imparted by concentric contraction, augmentation of nervous processes, and the release of some elastic energy stored in the connective tissues of the muscle complex" (Siff, 2000).

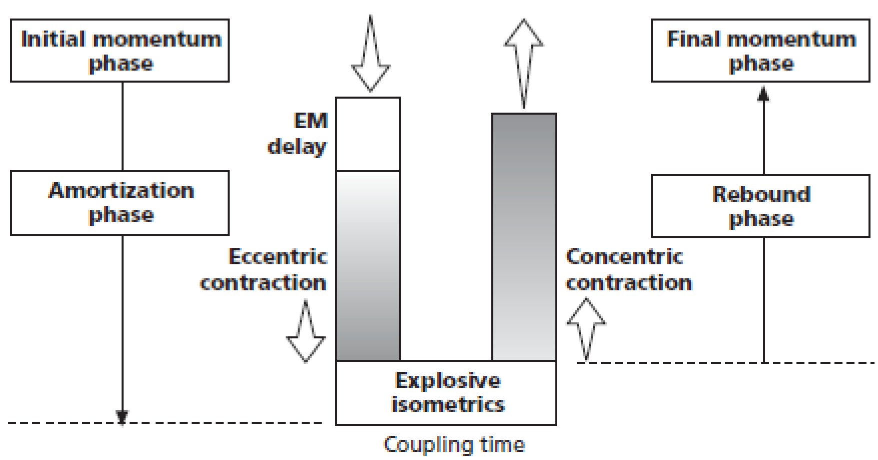

Figure 3. The different phases of a plyometric action.
EM delay=electromechanical delay between signal to end initial momentum phase and instant when eccentric contraction begins.

2.1.4.3 Coupling time

Coupling time has a ritical role in classifing any action as classical plyometric or not. it was stated Earlier that classical plyometric is described by a delay of no more than a fraction of a second between the eccentric and subsequent concentric contractions, a statement which requires some qualification. "For instance, research by Wilson et al. (1991) examining different delay times in the bench press, showed that the benefits of prior stretch may endure for as long as 4 s, at which stage it is suggested that all stored elastic energy is lost" (Wilson et al., 1991) (Fig. 4a).

Chapman and Caldwell (1985) found on the other hand, that" the benefits of prior stretching during forearm movement were dissipated within 0.25 s, a figure which agrees with other analyses of explosive rebound elbow flexion without additional loading" (Chapman & Caldwell, 1985) (Fig. 4b). Other study by Wilson et al. (1991) "examining rebound action of the chest/arms concluded that no benefits of prior stretching are evident after 0.37 s" (Wilson et al., 1991). This study suggest that delays of as long as a second or two can still produce significant augmentation of the subsequent concentric phase for some activities, but delays as short as 0.2 s are sufficient to dissipate the benefits of prior stretch during other activities, probably dependent on factors such as the mass of the limbs and the types of muscle fiber involved. Study by Bosco et al. (1983) offers a partial solution to this apparent contradiction. They proposed that "individuals with a high percentage of FT (fast-twitch) fibers in the leg muscles exhibit a maximum plyometric effect when the eccentric phase is short, movement range is small and coupling time is brief. On the other hand, subjects with a high percentage of ST (slow-twitch) fibers apparently produce their best jumping performance when the eccentric phase is longer, movement range is greater and the coupling time is longer, since the actin-myosin cross-bridging attachment time is of greater duration" (Bosco, Komi, Thihany, Fekete, & Apor, 1983).

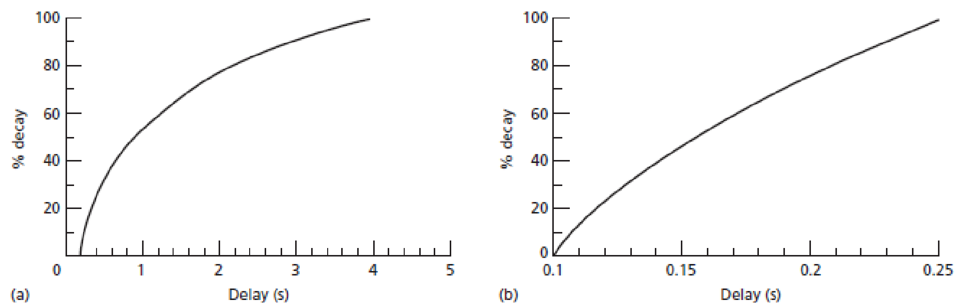

Figure 4. Effects of a time delay.
(a) “The effect of a time delay on the additional force produced by a preliminary stretch in a bench press (based on the data of Wilson et al., 1991) (b) The effect of a time delay on the additional force produced by a preliminary stretch in unloaded rapid elbow flexion” (Siff & Verkhoshansky, 1999).

Another reason not to attribute these differences in coupling times to the existence of particular maximum delays for each joint action. While this probably is true for different simple and complex joint actions, it should note also that the human body dislays many variuos reflexes, each of which acts under various conditions and at various rates.

In particular, there are static and dynamic stretch reflexes, and very guick receptors such as “Pacinian corpuscles in joint capsules that detect the rates of movement and allow the nervous system to predict where the extremities will be at any precise moment, thereby facilitating anticipatory modifications in limb position to ensure effective control and stability” (Siff, 2000). Loss of this predictive function obvously makes it in essence impossible to run, jump, throw or catch. “Other receptors such as the Ruffini endings and receptors in the ligaments like the Golgi tendon organs are strongly stimulated when a joint is suddenly moved, and after a slight initial adaptation they transmit a steady response” (Siff, 2000).

Furthermore, weightlifters and bodybuilders sometimes utilize the so-called pre-stretch principle to produce a more forceful concentric muscular contraction enabling them to lift heavier loads. They start a movement from a starting position which included an intense stretch on the working muscles, hold it for a couple of seconds and then thrust as strongly as possible from that position. This longer delay seems to include more tonic type of reflex with a longer coupling time. The action could doubtlessly not to termed plyometrics, in spite of the fact that prior stretch had contributed to the subsequent concentric action. In contrast, phasic reflex activity is more likely to be included in the explosive actions which typify classical plyometric and the type of activity depicted in Fig. 4.

This interpretation also serves to further distinguish between plyometric action and plyometric training. “One cannot simply distinguish between plyometric and non-plyometric solely on the basis of coupling times, otherwise one would have to classify jogging or even brisk walking as classical plyometric, because the time taken for the ground reaction force to reach a maximum can be less than 0.15 s. One also has to take the force–time pattern and the rate of force development (RFD) into account” (Siff, 2000).

2.1.4.4 Models or source contributions of plyometric training

The production of muscular power is best described by three proposed models: “mechanical, neurophysiological and the stretch-shortening cycle” (Coetzee, 2007)(Potash and Chu, 2008).

1. The mechanical model

The mechanical model explains that during an eccentric muscle action, elastic energy in the muscle- tendon complex is increased with a rapid stretch and then stored (Potash & Chu, 2008a). Significant increases in concentric muscle production occur when immediately preceded by an eccentric contraction. This increase might be partly due to this storage of elastic potential energy, since the muscles are able to utilize the force produced by the series-elastic component (SEC) (Voight & Tippett, 2004). SEC in the muscle plays an important role in this model (Coetzee, 2007). Even though all components of the SEC (tendon, actin, myosin, structural proteins) are stretched when a joint is loaded, the tendon is the main contributor to muscle-tendon unit length changes and the storage of elastic potential energy (Chmielewski, Myer, Kauffman, & Tillman, 2006). To maximize the power output of the muscle, the eccentric muscle action must be followed immediately by a concentric muscle action (Potash & Chu, 2008a; Radcliffe & Farentions, 1999). If a concentric muscle action does not occur, or if the eccentric phase is too long or requires too great motion about the given joint, the stored elastic energy is wasted as heat, and stretch reflex is not activated (Potash & Chu, 2008b; Voight & Tippett, 2004). For example, greater vertical jump height has been attained when the movement was preceded by a countermovement as opposed to a static jump (Voight & Tippett, 2004).

2. The neurophysiological model

The neurophysiological model involves the potentiation (force-velocity characteristics of the contractile components change with a stretch) of the concentric muscle action by use of the myotatic or stretch reflex. The stretch reflex is the body's involuntary response to an external stimulus that stretches the muscle (Potash & Chu, 2008b). Muscle spindles are amongst the special receptors that play a permanent role in the appearance of the myotatic stretch reflex. These proprioceptive organs are sensitive to the rate and magnitude of a stretch (McArdle, Katch, & Katch, 2001).

During plyometric exercise, or when the muscle is rapidly stretched, the stimulated muscle spindles cause a reflexive muscle action. The more rapidly the load is applied to the muscle, the greater the firing frequency of the spindle and resultant reflexive muscle contraction (Voight & Tippett, 2004). This reflexive response increases the activity of the agonist muscle, and increases the amount of force for the resultant concentric muscle action (Potash & Chu, 2008b). The rapid lengthening phase in the stretch-shortening cycle produces a more powerful subsequent movement. This is due to a higher active muscle state (greater potential energy) being reached before the concentric, shortening action, and the stretch-induced evocation of segmental reflexes that potentiate subsequent muscle activation (McArdle et al., 2001).

3. Stretch-shortening cycle model

The repeated sequence of eccentric (lengthening) contractions followed by a concentric, explosive, powerful muscular contraction is known as the stretch-shortening cycle (SSC) (Komi, 2003). The SSC uses the energy-storing capacity, the SEC and stimulation of the stretch reflex to facilitate a maximal increase in muscle recruitment over a minimal amount of time (Potash & Chu, 2008b). An effective SSC can only be achieved if the following basic conditions are met: first, a timed pre-activation of the muscles before the eccentric phase occurs; secondly, a short and fast eccentric phase; and finally, an immediate transition (minimal delay) from the eccentric to the concentric phase (Komi, 2003).

The SSC involves three distinct phases: the eccentric or loading phase, amortization or coupling phase[1], and the concentric or unloading phase. Phase One, the eccentric phase, involves preloading the agonist muscle group(s). Eccentric loading will place load upon the elastic components of the muscle fibers (Voight & Tippett, 2004). The SEC stores elastic energy and muscle spindles are stimulated. As the muscle spindles are stretched, they send a signal to the ventral root of the spinal cord via the Type 1a afferent nerve fibers. Phase Two, the amortization phase, is the electromechanical delay between the first (eccentric) phase and third (concentric) phase where alpha motor neurons then transmit signals to the agonist muscle group. Muscles must switch from overcoming work to acceleration in the opposite direction. The shorter the amortization phase, the greater the amount of force production (Potash & Chu, 2008b; Voight & Tippett, 2004). Phase Three, the concentric phase, is the body's response to the eccentric and amortization phases. When the alpha neurons stimulate the agonist muscles, they produce a reflexive concentric muscle action (Potash & Chu, 2008b). Most of the force that is produced comes from the fiber filaments sliding over each other (Voight & Tippett, 2004). The stored elastic energy in the SEC during the eccentric phase is used to increase the force of the subsequent isolated concentric muscle action (Potash & Chu, 2008b).

Plyometric exercises stimulate proprioceptive feedback to fine-tune for specific muscle-activation patterns. These exercises utilize the SSC, train the neuromuscular system by exposing it to increased strength loads and improve the stretch reflex (Wilk et al., 1993). Increased speed of the stretch reflex and increased intensity of the subsequent muscle contraction will amount to better recruitment of additional motor units. The force-velocity relationship postulates that the faster a muscle is loaded or lengthened eccentrically, the greater the resultant force output will be (Voight & Tippett, 2004).

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[1] *Amortization phase* is a term used to refer to the ECC phase plus prior delay seen between muscular activation via neural action potentials and muscle contraction [*electromechanical delay*]. *Coupling time* is a term used to refer to the length of the isometric (ISOM) phase between ECC and CON actions.

2.1.5 Land-based plyometric training

2.1.5.1 Explosive leg power

Plyometric training (PT) is a common method to enhance lower-extremity strength, power and stretch-shortening cycle (SSC) muscle function in healthy individuals (Markovic & Mikulic, 2010). The ability to produce force rapidly is vital to athletic performance. Increases in power output are likely to contribute to improvements in athletic performance (Potteiger et al., 1999). The transfer of these plyometric effects for athletic performance is most likely dependent upon the specificity of the plyometric exercises performed. Specific plyometric exercises can be used to train the slow or fast SSC. Examples of slow SSC plyometric include vertical jumps and box jumps. Bounding, repeated hurdle hops, and depth jumps, typically, are regarded as fast SSC movement (Flanagan & Comyns, 2008). Athletes who require power for moving in the horizontal plane (e.g. sprinters and long jumpers) mainly engage in bounding plyometric exercises, as opposed to high jumpers, basketball or volleyball players who require power to be exerted in a vertical direction and who perform mainly vertical jump (VJ) exercises (Markovic & Mikulic, 2010). These training adaptations are in accordance with the principle of specificity (McArdle et al., 2001).

In the literature appropriate plyometric training programs have been shown to increase power output (Luebbers et al., 2003). agility (Miller, Herniman, Ricard, Cheatham, & Michael, 2006). running velocity ((Kotzamandisis, 2006). and also running economy (Turner, Owings, & Schwane, 2003).

2.1.5.2 Neuromuscular changes for power development

Plyometric training (PT) either alone or in combination with other typical training modes (e.g. weight training [WT] or electromyo-stimulation), elicits many positive changes in the neural and musculoskeletal systems, muscle function and athletic performance of healthy individuals (Markovic & Mikulic, 2010). The ability of the neuromuscular system to produce power at the highest exercise intensity, often referred as ‘muscular power’ is an important determinant of athletic performance (Paavolainen, Hakkinen, HA-Malainen, Nummela, & Rusko, 1999).

Markovic and Mikulic 2010 stated: “the adaptive changes in neuromuscular function due to PT are likely to be the result of (I) an increased neural drive to the agonist muscles (II) changes in the muscle activation strategies (i.e. improved inter-muscular coordination). (III) changes in the mechanical characteristics of the muscle-tendon complex of plantar flexors; (IV) changes in muscle size and/or architecture; and (V) changes in single-fiber mechanics (Markovic & Mikulic, 2010, p. 860).

Adams et al. (1992) compared “6 weeks of squat, plyometric, or combined squat and plyometric training on power production. The periodized squat program consisted of a 2-day-per-week frequency where the Tuesday workout was higher in intensity than the Friday workout. Tuesday workouts consisted of 2–4 sets of 2–8 repetitions using 70%–100% of 1 RM whereas Friday workouts consisted of 1–2 sets of 8 repetitions using 50%–70% of 1 RM. The plyometric training program consisted of depth jumps, double-leg hops, and split squats (walking and standing). Depth jumps initiated from a 51-cm height and increased each week reaching 114 cm by week 6 and were performed for 2–3 sets of 6–10 repetitions. The double-leg hops were performed for 2–3 sets of 15 m and the split squats were performed for 1–3 sets of 15 m (walking) and 1–3 sets of 6–10 repetitions (in place). The combination program consisted of both RT and plyometric training programs. The combination of RT and plyometric training produced the most substantial increases in vertical jump (10.67 cm). Individually, RT and plyometric training each produced comparable increases in vertical jump performance (3.3 and 3.81 cm, respectively)” (Adams, O’Shea, O’Shea, & M, 1992). These data explain the significance of incorporating plyometric and resistance training for maximizing lower-body power.

Potteiger et al. (1999) showed that a plyometric training (PT) program could bring about significant increases in leg extensor muscle power and whole muscle fiber hypertrophy. In an eight-week, threes day per week plyometric and aerobic exercise program, changes in muscle power output and fiber characteristics following this intervention were examined. A group of 19-physically active men aged 21.3 ± 1.8 years were randomly selected to either a plyometric-group or combination-group of PT and aerobic exercise. The PT consisted of vertical jumps (VJ), bounding, and 40- centimeters (cm) depth jumps. The aerobic exercise was performed at 70 percent (%) heart-rate maximum (HRmax) for 20-minutes immediately following the plyometric workouts. Muscle biopsy specimens were taken from the vastus lateralis (VL) muscle before and after training. Type I (slow twitch) and Type II (fast twitch) muscle fibers were identified and cross-sectional areas (CSA) calculated. Peak and average muscle power output were measured using countermovement vertical jump (CMJ). No significant differences were found between the groups following training for either peak or average power. Both groups displayed significant increases from pre-testing to post-testing for both peak and average leg extensor muscle power. The plyometric-group increased by 2.8% and 5.5%, for peak power and average power, respectively. The combination-group increased by 2.5% in peak power and 4.8% average power, respectively .VJ height improved in each group from pre-training to post-training. The plyometric-group increased peak power and average power by 2.8% and 5.5%, respectively. Each group demonstrated a significant increase in muscle fiber CSA from pre-training to post-training for Type I (plyometric group, 4.4%; combination-group 2, 6.1%) and Type II (plyometric-group 7.8%; combination-group 2, 6.8%) fibers, with no differences between the groups. The improved CMJ and increased power output following the PT were most likely due to a combination of the enhanced motor unit recruitment patterns and increased muscle fiber CSA, caused by fiber hypertrophy in both slow twitch and fast twitch fibers (Potteiger et al., 1999).

Malisoux et al. (2006a) on the other hand, focused on the contractile properties of single fibers of VL muscle of recreationally active men (n= 8; age: 23 ± 1 years). After eight weeks of PT induced significant increases in peak force and maximal shortening velocity in the myosin heavy chain (MHC) isoforms Type I, IIa and hybrid IIa/IIx fibers, while peak power increased significantly in all fiber types. PT significantly increased maximal leg extensor muscle force, and VJ performance was also improved 12% ($p<0.01$) and 13% ($p<0.001$), respectively. Peak force increased 19% in Type I ($p<0.01$), 15% in Type IIa ($p<0.001$), and 16% in Type IIa/IIx fibers ($p<0.001$). Maximal shortening velocity increased 18, 29, and 22% in Type I, IIa, and hybrid IIa/IIx fibers, respectively ($p<0.001$). Single-fiber CSA increased 23% in Type I ($p <0.01$), 22% in Type IIa ($p<0.001$), and 30% in Type IIa/IIx fibers ($p<0.001$), in VL muscle following the PT-intervention (Malisoux, Francaux, Nielens, & Theisen, 2006 a).

Potteiger et al. (1999) also reported significant increases in Type I and type II fiber CSA of the VL muscle, but these effects were of lesser magnitude (6–8%)(Potteiger et al., 1999). Malisoux et al. (2006b) also found a significant increase in the proportion of type IIa fibers of the VL muscle (Malisoux, Francaux, Nielens, Renard, et al., 2006 b). In contrast, Potteiger et al. (1999) did not observe any significant changes in fiber-type composition of the VL muscles (Potteiger et al., 1999).

Contradictory to the above research, Kyröläinen et al. (2005). found that 15-weeks of maximal-effort PT performed by recreationally active men (n=23; age 24 ± 4 years) showed no significant changes in muscle fiber type or size. Plantar flexor strength did improve with significant increases in muscle activity, but not the rate of force development (RFD) and without any changes in either the muscle fiber distributions or CSA. Although no changes were found in the maximal strength or muscle activation for knee extensor muscles, the enhancements in jumping performance were due to improved joint control and increased RFD at the knee joint (Kyröläinen et al., 2005).

In contrast, Kubo et al. (2007) showed in a 12-week comparative study of PT and WT upon untrained male participants (n=10; age: 22 ± 2 years), PT induced changes in the strength of plantar flexors, but not in that of the knee extensors. Plantar flexors showed significant hypertrophy and significant increases in maximal voluntary contraction with increased muscular activation (Kubo et al., 2007).

Studies that showed significant changes in a single fiber function (Malisoux et al., 2006a; 2006b) due to PT were also accompanied by significant improvements in the whole muscle strength and power. The noteworthy results of Malisoux et al. (2006a) suggest that PT-induced improvements in muscle function and athletic performance could be partly explained by changes in the contractile apparatus of the muscle fibers, at least in the knee extensor muscles.

Plyometric training (PT) exercises require a high level of eccentric force to stabilize and control the knee and hip joint. A high level of concentric quadriceps and hamstring muscle force development is also needed for perpetuation and momentum during PT movements. To determine the effect of PT on the knee extensor and flexor muscles, Wilkerson et al. (2004) studied the neuromuscular changes in 19-university women basketball players (age: 19 ± 1.4 years). A six-week plyometric jump training program was completed as part of their pre-season conditioning. Concentric isokinetic peak torque of the hamstrings and quadriceps were measured before and after the intervention at 60º·s-1 and 300º·s-1. The experimental group (n=11) completed stretching, isotonic WT and structured PT under the supervision of the researcher. The control-group (n=8) also participated in stretching, isotonic WT and a periodic performance of unstructured PT under the supervision of the team's basketball coaches. Data was also collected from the quadriceps and hamstring muscles during a forward lunge test, called the unilateral step-down test. Results showed a significant increase for hamstrings' peak torque at 60º·s-1 (p=0.008) in the experimental group, while only three of the eight participants in the control-group showed an increase. The hamstrings did not show a significant increase at 300º·s-1 for the experimental group. There were no significant increases in quadriceps muscle torque at either 60º·s-1 and 300º·s-1 isokinetic test velocities. Therefore, PT increased the performance capabilities of the hamstring muscles, but not the quadriceps muscles. An improvement in the hamstring muscle strength stabilizes and controls the eccentric movement through the hip and knee whilst the body is in motion (Wilkerson et al., 2004).

In the above literature, PT induced significant improvements in neuromuscular function for power development. PT appears to enhance motor unit recruitment patterns, with increases in muscle fiber hypertrophy for optimal maximal power output. PT significantly increased maximal leg extensor muscle force, with improved CMJ performance and increased RFD at the knee joint in recreationally active males. These changes were accompanied with increased muscle fiber CSA in whole muscle and in single fiber studies. PT has also significantly improved maximal shortening velocities of leg extensor muscles. Plyometric exercises can too optimize performance and assist with injury prevention by improving hamstring strength, eccentric control and stability of the pelvis and knee.

2.1.5.3 Vertical jumping performance

A critical physical attribute and key component for successful performance in many athletic events is explosive leg power. An excellent example of this is vertical jumping ability, as there is a strong association between increased lower body power and vertical jump (VJ) height (Potteiger et al., 1999).

The vertical jump include five distinct phases: "(a) starting position, (b) countermovement, (c) jump or propulsion, (d) flight, and (e) landing. Athletes generate greatest force applied to the ground, power, and jump height from a hip-to-shoulder width stance. The countermovement is characterized by rapid hip and knee flexion, ankle dorsiflexion, and shoulder hyperextension. The jump or propulsion phase consists of explosive hip, trunk, and knee extension, plantar flexion, and shoulder flexion. Take-off velocity during the vertical jump is affected by: knee extension, 56%; plantar flexion, 22%; trunk extension, 10%; arm swing, 10%; and head swing, 2%" (Luhtanen & Komi, 1978). "In the lower body during propulsion the hip, knee, and ankle contribute 40%, 24.2%, and 35.8% to the forces applied to the ground, respectively" (Robertson & Fleming, 1987). literature have documented the significant of the counter-movement and arm-swing in maximizing power and height attained during the vertical jump (Harman, Rosenstein, Frykman, & Rosenstein, 1990). The arm-swing consists of an explosive forward and upward movement of the arms with the thumbs up. The "arm-swing helps to keep the torso upright especially as the hips flex. Flight time increases in proportion to the vertical height attained and is dependent upon the power produced by the athlete. The landing style is critical to absorbing shock and minimizing joint stress. Lowering peak ground reaction force and increasing braking (by flexing the knees, hips, and dorsiflexing the ankles for better force distribution and shock absorption) is important. Greater stress is seen during a single-leg landing (greater valgus stress on knee, higher muscle activation, less knee flexion to absorb force) than during a double-leg landing" (Pappas, Hagins, Sheikhzadeh, Nordin, & Rose, 2007). "Women show greater valgus stress on the knee and greater relative ground reaction force during double-leg landings compared to men" (Pappas et al., 2007). "Teaching proper landing mechanics is important to reducing the risk of injuries. Proper breathing consists of inhaling during the countermovement, temporary holding of breath during max propulsion, and exhalation upon elevation off of the ground" (Radcliffe & Farentions, 1999).

Some studies have shown that plyometric training (PT) has improved VJ performance 7; (Kubo et al., 2007; Markovic, Jukic, Milanovic, & Metikos, 2007;

Thomas, French, & Hayes, 2009), whereas other studies have not found any significant improvements (Sáez-Sáez De Villarreal, Gonzalez-Badillo, & Izquierdo, 2008; Vescovia, Canavan, & Hasson, 2008). The absence of such significant findings may be due to the difference in training programs in terms of intensity or volume, and possibly that the training program was not specifically designed to improve power and enhance performance. There is also the possibility that the VJ test was not sensitive enough to detect small but significant changes in power.

To determine the effect of different plyometric exercises upon VJ performance, Thomas, French and Hayes (2009) found that both depth jump (DJ) and CMJ plyometric training (PT) techniques were effective in improving power and agility in young soccer players. The comparative study used 12-males from a semiprofessional football club academy (age: 17.3 ± 0.4 years), randomly assigned to either six-weeks of DJ or CMJ training twice weekly. The participants were assessed for leg power, sprint speed and agility pre-and post-six-weeks. Participants in the DJ group performed DJ (40cm), with instructions to minimize ground-contact time while maximizing height. Participants in the CMJ-group performed jumps from a standing start position with instructions to gain maximum jump height. Post-training data showed that both groups experienced improvements in VJ height ($p<0.05$) without there being any differences between the treatment groups ($p>0.05$). DJ-training revealed a large practical significance of 1.1 and the CMJ-training demonstrated a medium practical significance with an effect size of 0.7. The study concluded that both DJ and CMJ plyometrics are worthwhile training activities for improving vertical power, particularly in trained, adolescent soccer players (Thomas et al., 2009).

Gehri et al. (1998) also established that DJ training was superior to CMJ training for improving both VJ height, and improved concentric muscular performance. The study sought to establish which PT technique was best for improving VJ ability, positive kinetic energy production (Epos) and elastic energy utilization. A group of 28- participants performed 12-weeks of jump training under three conditions of squat jump (SJ), CMJ, and DJ. Participants were randomly assigned to one of three groups, merely control, DJ-training, and CMJ-training. Pre- and post–testing of the SJ, CMJ, and DJ were completed upon a force-plate for vertical ground reaction force computations. VJ height, Epos and elastic energy were calculated using methods from Komi & Bosco (1978). Epos was calculated in the SJ trials which represent contractile performance on a pure concentric contraction. DJ and CMJ participants executed a SSC (eccentric to concentric). For both groups, an increase in Epos over that of the SJ reflected a utilization of stored elastic energy (Gehri, Richard, Kleiner, & Kirkendall, 1998).

Gehri et al. (1998) demonstrated that improved VJ ability following CMJ or DJ training was due to improved contractile component rather than elastic component performance. There were significant increases in VJ height for both training groups, although neither of the training methods improved utilization of elastic energy. DJ was superior to CMJ because of its neuromuscular specificity. CMJ training group only improved VJ height and Epos production in the SJ and CMJ, while the DJ training group improved VJ height and Epos production in all three jumping conditions. DJ training more closely approximates sport-specific jumping, with a greater application to sport than SJ or simple CMJ, again due to neuromuscular specificity. From a training stand-point, DJ must still be combined with other sport-specific jumps to further complement the athlete's overall training program.

It should be noted that in contrast to all the above research, some studies reported no change (Vescovia et al.,2008) or even showed a slight decrease in VJ performance initially following a PT intervention (Luebbers et al., 2003). Leubbers et al. (2003) compared the effect of two PT programs, of four or seven weeks in duration, on anaerobic leg power and VJ performance followed by a four-week recovery period of no PT. Physically active, college-aged men were randomly assigned to either a four week (n=19) or a seven-week program (n=19). The results showed an initial decline in VJ height directly at the end of the PT-intervention. However, after four weeks of recovery, the participants' performance increased significantly in the four week plyometric intervention group by 2.8% (67.8 ± 7.9 to 69.7 ± 7.6 cm; $p<0.05$), and increased 4% (64.6 ± 6.2 to 67.2 ± 7.6 cm; $p<0.05$) in the seven-week plyometric intervention group (Luebbers et al., 2003).

Vescovia et al. (2008) did not observe any improvements in jumping performances following a six-week PT intervention in recreationally athletic college-aged women. A group of 20-college-aged, female recreational basketball players were assigned to a training (n=10) or control (n=10) group. The investigators examined the effect of a PT program on peak vertical ground reaction force as well as on kinetic jumping characteristics of CMJ height, peak and average jump power, and peak jump velocity. The intervention group did show a clinically meaningful decrease in vertical ground reaction force (-222.87 ± 10.9 N) versus the control-group (54±7257.6 N), with no statistical differences between the groups (p=0.122). There were no differences in absolute change values between groups for CMJ height (1.0 ± 2.8 cm versus -0.2 ± 1.5 cm; p=0.696) or any of the associated kinetic variables following the six-week intervention. Eight of the ten women in the training group reduced vertical ground reaction force by 17–18% but no significant improvements in jumping performance were observed. Small sample size and limited statistical power negated the study's results. The PT-intervention was not focused on jump performance enhancement but to reduce landing forces in recreationally athletic women (Vescovia et al., 2008).

According to two meta-analysis studies into whether plyometric training improves VJ (Markovic, 2007; Sáez-Sáez De Villarreal, Kellis, Kraemer, & Zquierdo, 2009), and a review of physiological adaptations for PT (Markovic & Mikulic, 2010) (VJ) performance can be assessed using all four types of standard vertical jumps such as squat jumps (SJ), countermovement jumps (CMJ), CMJ with the arm swing (CMJA) and depth jumps (DJ).

Markovic (2007) summarized: "PT provided both statistically significant and practically relevant improvement in VJ height with the collective mean effect ranging from: 4.7% for both SJ and DJ, over 7.5% for CMJA, to 8.7% for CMJ". However in a more recent review, Markovic & Mikulic (2010: 876, 880) concluded: "PT considerably improved VJ height; upon a collective mean effect ranging from: 6.9% (range, -3.5% to +32.5%) for CMJA, over +8.1% (range, -3.7% to +39.3%) for SJ, and 9.9% (range, -0.3% to +19.3%) for CMJ, to 13.4% (range, -1.4% to +32.4%) for DJ" (Markovic, 2007, p. 355).

The relative effects of PT are likely to be higher in fast SSC VJ (DJ) than in slow SSC VJ (CMJ and CMJA) and concentric-only VJ (SJ) (Gehri et al., 1998; Markovic & Mikulic, 2010). The landmark study by Wilson, Newton, Murphy and Humphries (1993) suggested that PT was more effective in improving VJ performance in fast SSC jumps as it enhances the ability of participants to use neural, chemo-mechanical and elastic benefits of the SSC. PT can enhance both slow and fast SSC muscle function, but these effects are specific to the type of SSC exercise used in training (Markovic & Mikulic, 2010). It was therefore more beneficial to combine different types of plyometric than to use only one form, whereas the best combination was SJs + CMJs + DJs (Gehri et al., 1998; Sáez-Sáez De Villarreal et al., 2009).

The above literature demonstrated that PT could induce significant improvements in VJ. Vertical power was significantly improved using a plyometric intervention of both DJ and CMJ plyometric exercises. DJ training appeared to be more effective as it more closely approximated sport-specific jumping, with a greater application to sport than SJ or simple CMJ, due to neuromuscular specificity. Furthermore it would be more beneficial to combine different types of plyometric than to use only one form, whereas the best combination was SJs + CMJs + DJs. Additionally, utilizing combination training of PT and WT could exhibit significantly better VJ performances than with PT or WT alone upon VJ height, jumping mechanical power, and flight time.

2.1.5.4 Horizontal jumping performance

The horizontal jump (e.g, standing broad/ long jump) has long been utilized by athletics coaches as a simple, direct, field-based test for athletic performance in sprinting and long jump athletes. These athletes require rapid, explosive leg power in the horizontal plane specific to their sport, in accordance with the principle of specificity. Movements requiring a powerful thrust from hips and thighs can be improved through the prescription of a biomechanically similar movement during training (Adams, O'Shea, O'Shea, & Climstein, 1992). Short-term PT can be significantly beneficial to improve horizontal explosive performances in trained and untrained participants, using sport-specific PT exercises (Adams, O'Shea, O'Shea, & Climstein, 1992; Markovic et al., 2007), a combination training of weight training (WT) and PT (A. D. Faigenbaum et al., 2007) or with real-time feedback after PT performances to help maintain training targets and intensity thresholds (Randell, Cronin, Keogh, Gill, & Pedersen, 2011).

Faigenbaum et al. (2007) compared the effects of a six-week training period of combined plyometric and resistance training (n=13; age: 13.4 ± 0.9 years) and weight training alone (WT, n=14; age: 13.6 ± 0.7 years) on fitness performance in young male participants. The combination-group made significantly ($p<0.05$) greater improvements than the WT-group in the standing long jump, being 10.8 cm (6%) versus 2.2 cm (1.1%). These results possibly indicate that a combination of PT and WT may be beneficial for enhancing horizontal jumping performances (Faigenbaum et al., 2007).

Previous research of Adams et al. (1992) has shown that the use of squat jump (SJ) during training may result in improvements in horizontal jump performances. The initial squat and lower body triple extension movement enhances neuromuscular efficiency, and allows for excellent transfer of biomechanically similar movements, as seen in the VJ and horizontal jumps (Adams, O'Shea, O'Shea, & M, 1992).

Randell et al. (2011) showed that the use of feedback during squat jump training in conjunction with a six-week pre-season conditioning program, proved beneficial to increasing performances of sport-specific tests, including the horizontal jump. A group of 13 professional rugby players were randomly assigned to either a feedback (group 1; n=7) or a non–feedback group (group 2; n=6). Group 1 was given real-time feedback on peak velocity of the concentric SJ at the completion of each repetition using a linear position transducer, whereas group 2 did not receive any feedback. The feedback group showed a 2.6% improvement in HJ performances versus 0.5% in the non-feedback group. With the use of feedback within training, to optimize performance improvements, a 83% chance of having a positive effect on HJ performance was reported, and a small training effect noted (effect size [ES] = 0.28) (Randell et al., 2011).

In contrast to the above studies, Markovic et al. (2007b) found that short-term sprint training produced similar or even greater training effects in muscle function and athletic performances than PT in untrained college students. The sprint training improved the linear explosive performance of horizontal jumps greater than PT, in the 10-week, three-days per week intervention. A group of 93-male physical education students were assigned randomly to one of three groups: a sprint-group (n=30), a plyometric-group (n=30), and a control-group (n=33). Both experimental groups trained. The sprint-group performed maximal sprints over distances of 10–50 m, whereas plyometric-group performed bounce-type hurdle jumps and depth jumps. The control-group maintained their daily physical activities. Both the sprint- and plyometric-groups significantly

($p<0.001$) improved in standing long jump (3.2%; ES=0.5 versus 2.8%; ES=0.4). These improvements were significantly ($p<0.001$) higher compared with the control-group. No significant differences were found between sprint- and plyometric-groups for the standing long jump ($p=0.78$) (Markovic et al., 2007). In addition to the well-known training methods, such as WT and PT, incorporating sprint training into an overall conditioning program may assist athletes to achieve high levels of explosive leg power and dynamic athletic performance, such as the horizontal jump.

Hortobagyi, Havasi and Varga (1990) did not support the previously stated assumption that PT can be trained in a specific plane of movement, either vertical or horizontal, in accordance with the principle of specificity. The landmark study by Hortobagyi et al. (1990) divided a group of 40-primary school boys (age: 13.4 ± 0.11 years) into two experimental groups to perform two distinctly different PT routines of either vertical or horizontal specific PT. Neither experimental group yielded specific gains in performance. There was too high a degree of generality between the jumping tests performed, as the vertical and horizontal jumping tests were highly correlated thereby negating the notion of movement plane specificity for PT (Hortobagyi, Havasi, & Varga, 1990).

PT intervention may significantly improve horizontal explosive performances in trained and untrained participants. Combination training of WT and PT utilizing young, male participants performed significantly better than WT alone in the standing long jump. The use of real-time feedback on peak velocity of SJ performances in professional rugby conditioning program has produced larger improvements in horizontal explosives performance than non-feedback participants. Although in untrained male, university students, sprint training could be slightly more effective, and practically more significant than PT upon horizontal jump performances.

2.1.5.5 Effect of plyometric training upon muscular strength and endurance

It is suggested that lower limb strength performances can be significantly improved by plyometric training (PT). When plyometric exercises are performed with adequate technique, these training gains are independent of the fitness level or sex of the participant. PT has been shown to improve maximal strength performances, measured by one-repetition maximum (1RM), isometric maximal voluntary contraction (MVC) or slow velocity isokinetic testing (Sáez-Sáez De Villarreal, Requena, & Newton, 2010).

Vissing et al. (2008) showed that weight training (WT) and PT seemed to lead to similar gains in maximal strength, whereas PT induced far greater gains in muscle power. The study compared the changes in muscle strength, power, and morphology induced by WT versus PT. Young, untrained male participants (age: 25.1 ± 3.9 years) performed 12-weeks of progressive WT (n=8) or PT (n=7). Tests included 1RM incline leg press, 3RM knee extension, and 1RM knee flexion, countermovement jumping (CMJ), and ballistic incline leg press. Muscle strength increased by approximately 20–30% (1–3RM tests) ($p<0.001$), with WT showing a 50% greater improvement in hamstring strength than PT ($p<0.01$). For the 1RM inclined leg press, the WT-group increased leg strength by 29 ± 3% ($p< 0.001$) and PT group improved by 22 ± 5% ($p <0.01$) with no significant differences present between the groups. In the 3RM isolated knee extension, WT increased by 27 ± 2% ($p<0.001$) and PT increased by 26 ± 5% ($p<0.001$). In the 1RM hamstring curl, WT increased by 33 ± 3% ($p<0.001$), which was larger than the 18 ± 4% improvement in PT ($p<0.05$). PT increased maximum CMJ height 10% and maximal power by 9% ($p<0.01$). PT increased maximal power in the ballistic leg press 17% ($p<0.001$) versus WT 4% ($p<0.05$); this was significantly greater than WT ($p<0.01$). Gains in maximal muscle strength were essentially similar between the PT and WT groups, whereas muscle power increased almost exclusively with PT-training (Vissing et al., 2008).

Fatouros et al. (2000) found that athletic training combining both PT with traditional and Olympic-style weightlifting exercises showed significantly greater improvement ($p<0.05$) in 1RM back squat and 1RM leg press when compared with PT alone. In a 12-week intervention of three training sessions per week (3d·wk-1), 41-untrained men (age: 20.7 ± 1.96 years) were assigned to one of the four-groups: PT (n=11), WT (n=10), plyometric plus weight training (n=10), and control (n=10). WT showed greater improvements than PT in maximal leg strength measured by the leg press, whereas maximal strength measured by the back squat showed equal increases by both groups. These findings were attributed to the nature and specificity of the plyometric and weight-training exercises prescribed during the 12-week intervention.

Fatouros et al. (2000) also measured average leg muscle endurance by means of repeated jumps using the Vertical Jump test by Bosco et al. (1983), pre- to post-test, to calculate jumping mechanical power. This test was selected because it took advantage of the potential for using elastic energy storage in addition to chemical-mechanical energy conversion. The test had a high validity (compared with the Wingate test [WAnT] (r=0.87) and reliability (test-retest, r=0.95) coefficients (Bosco et al., 1983). The test calculated mechanical power both for 15- and 60-second jumping intervals. Participants executed maximal, repeated vertical jumps for 15-seconds to calculate average power output and flight time. A 15-second jumping interval was selected, as it reflected real jumping conditions in sports performance and also exhibited a high validity coefficient when compared with the WAnT power test (Bosco et al., 1983). The combination training group (PT plus WT) exhibited significantly ($p<0.05$) better vertical jump (VJ) performances than the PT- and the WT-groups in VJ height, jumping mechanical power and flight time(Fatouros et al., 2000).

In contrast to the above research, Markovic et al. (2007b) found that short-term sprint training produced even greater training effects in muscle strength than PT. Pre- and post-testing, leg extensor muscle strength was assessed by means of an isometric squat test. After a 10-week intervention, only the sprint-training experimental group significantly improved isometric leg extensor strength by 10% (p=0.002; ES=0.4). This improvement was significantly greater than the PT experimental (p=0.04) or control group (p=0.02) (Markovic et al., 2007).

In the above literature, muscular strength was improved by PT alone but larger increases in leg strength were attained by WT alone or combination training. In untrained, male participants completing WT alone showed larger improvements in leg extensor and flexor strength than by means of PT alone (Vissing et al., 2008). Combining both PT with traditional and Olympic-style weightlifting exercises displayed significantly higher improvements in 1RM back squat and 1RM leg press when compared with PT or WT alone, in untrained men (Fatouros et al., 2000).

Average leg muscle endurance by means of repeated jumps to calculate jumping mechanical power (Fatouros et al., 2000), indicated that combination training could exhibit significantly better VJ performances than the PT- and WT-groups in VJ height, jumping mechanical power, and flight time On the contrary, short-term sprint training has also produced significantly greater training effects than PT in leg extensor strength by means of an isometric squat test, in untrained university men (Markovic et al., 2007 b).

Strength improvements could be significantly higher when plyometric are combined with other types of exercises (e.g. plyometric + weight-training and plyometric + electrostimulation) than with PT alone. A combination of different types of plyometric jumps with WT would be more beneficial than utilizing a single jump type. Performance outcomes of a PT or combination training program are very specific to the nature and specificity of the plyometric and weight-training exercises prescribed.

2.1.5.6 Upper body plyometric training

Upper body plyometric training (PT) is essential for athletes who require upper body power (Newton et al., 1997; Wilk et al., 1993). Any exercise using an eccentric pre-stretch followed by an explosive concentric contraction is plyometric in nature. Various forms of exercise can be used to exploit the stretch reflex, as the musculature of the upper body possesses the same physiological characteristics of the lower body (Potash & Chu, 2008a).

The push-up exercise can be used within a simple PT program to develop power in the shoulder girdle region (Voight, Draovitch, & Tippett, 1995). Vossen, Kramer, Burke and Vossen (2000) compared the effects of dynamic push-up training and plyometric push- up training upon strength and power of the upper body. A group of 35 recreationally active women were randomly divided into a dynamic push-up group (n=17) and a plyometric push-up group (n=18), completing 18-training sessions, three days per week, over a six-week period. The participants performed two-tests of measuring the power and strength of shoulder and chest, before and after the six-week intervention. Tests included the two-handed medicine ball put, and one repetition maximum (1RM) seated chest press. In the medicine ball put, the plyometric push-up group experienced significantly greater increases than the dynamic push-up group ($p<0.05$). In the chest press, the plyometric push-up group demonstrated a slightly greater improvement than the dynamic push-up group pre-to post-test, but there were no significant differences between the two groups. These results showed that the plyometric push-up was more effective than dynamic push-up in developing upperbody power and strength. It still remains unclear whether upper body PT could translate into improvements in athletic performance (Vossen, Kramer, Burke, & Vossen, 2000).

Santos and Janeira (2011) studied the effects of PT explosive strength in adolescent male basketball players (age: 14 to 15 years). An experimental group and controlgroup were utilized. The experimental group performed a 10-week in-season PT program, twice weekly, along with regular in-season basketball practice. Simultaneously, the control-group participated in regular basketball practice only. For the upper-body, explosive strength test-battery in the 3-kg medicine ball throw, the experimental group improved 14.9% pre- to post-testing, as against the control improving 5.5% after the 10-week intervention. This shows a significant difference between the groups ($p<0.001$). Conclusively, PT showed positive effects on explosive strength of the upper and lower-body in adolescent male basketballers. Faigebaum et al. (2007) showed similar results in a study exploring the effects of combination training (PT and weight training) as against weight training (WT) only, in adolescent participants. For the upper-body explosive power test, the combination training group improved 14.4% upon the 3.6-kg medicine ball throw pre- to post-testing, versus the WT of 5.6% in the six-week intervention. It was thus significantly greater than the WT ($p<0.05$) (Santos & Janeira, 2011).

The above upper body PT literature found the plyometric push-up could be a more effective in developing upper-body power and strength than a dynamic push-up, in recreationally active females. In active adolescent males, upper body power was significantly improved with concurrent in-season training and additional PT than participants just maintaining in-season training. Furthermore, combination training demonstrated greater gains in upper body explosive power than WT alone, in adolescent males.

Upper body PT is acknowledged as a highly viable, useful, and necessary PT mode, but was not the focus of this theoretical review of lower body plyometrics. Further study would be highly recommended for exploring upper body PT alone, or alternatively, combined with lower body PT in trained and untrained athletes participating in power-based sports such as rugby union. The use of upper body PT in water compared to land-based upper body PT would be a useful addition to research.

2.1.5.7 Other training responses to plyometric training

The benefits of plyometrics seem to lie in the fact that it may promote changes within the neuromuscular system that enhances neuromuscular efficiency. A cognitive learning effect and increase in the fiber area of type II muscle fibers can also occur due to plyometric training (PT) (Coetzee, 2007).

Makaruk and Sacewicz (2010) showed that irrespective of the level of jumping ability of the participants, maximal leg power output may be significantly improved using specific verbal cueing instructions during PT. These verbal instructions emphasize improving the speed of execution during PT, minimizing ground contact, and significantly improving in maximal power output. Study participants were 44 mixed male and female, untrained university students (age: 20.5 ± 0.5 years). Experimental group performed plyometric exercises for six weeks, whereas the control-group participated only in attending lectures. The study test battery consisted of countermovement (CMJ), depth jump DJ (31cm) and a five-hop test (5JT). Post testing results showed significant increases in relative maximal power output for CMJ ($p \leq 0.05$) and DJ ($p \leq 0.01$). Centre of mass elevation and the 5JT distance length did not change significantly ($p > 0.05$). DJ rebound time was significantly shorter ($p \leq 0.01$) with significantly lower knee flexion angles ($p \leq 0.01$) (Makaruk & Sacewicz, 2010). Thus, performing jumps with the fastest possible rebound and the shortest ground contact time improved maximal power output with no effect from jumping ability. Use of specific verbal cueing significantly affected the direction and size of changes in new skill acquisition of explosive activities such as plyometric exercises.

Hutchinson, Tremain, Christiansen and Beitzel, (1998) suggested that PT improves sports performance because of a cognitive learning effect. Hutchinson et al. (1998) used jump training to improve the leaping ability of elite rhythmic gymnasts. A group of six elite female athletes (average age: 16-years) participated in the leap training; researchers included a control-group consisting of two other participants. Testing included reaction time, leap height, explosive power, and was performed on a force plate. Testing was done before the intervention, after one month of training, and after an additional three months training. Three athletes were also retested after one year of maintenance protocol training, although they continued intense training for an international competition. The athletes underwent jump training which included pool training with aquatic plyometric training (one hour, twice a week). They also participated in Pilates' Method classes (twice a week during the first month, and once a week thereafter). After one month of training, the experimental group improved leap height by 16.2%, ground contact time by 50% and explosive power by 220%. After three months of continued maintenance, there were no further significant improvements in any of the tested variables. The control-group showed no significant changes after the first month or an additional three months. The three participants, who were retested after one year, showed that their initial gains were maintained. As there were no additional achievements from pre-training levels after one year. Hutchinson et al. (1998) supported the hypothesis that jump training is more likely a cognitive, learned outcome rather than simply a motor strengthening effect (Hutchinson, Tremain, Christiansen, & Beitzel, 1998).

2.1.6 Plyometric Training for Youngers

Although plyometric have commonly been viewed as only appropriate for conditioning elite adult athletes," Children and adolescents benefit from plyometric training and plyometric-like exercises" (Potash and Chu, 2008a). Plyometrics training could help children and adolescents to be fit physically and prepared them sufficiently for various youth sports. "Many activities and games (hopscotch) children play are plyometric in nature (activate the SSC) so the thought of plyometric training in youth is not novel. Plyometric training in children and adolescents has been embraced by prominent S&C[2] organizations" (Faigenbaum, Kraemer, Blimkie, & Al, 2009). "Some misconceptions concerning plyometric training in youth is that it is unsafe (causes growth plate injuries) and children lack the necessary strength needed to engage in a training program. However, research does not support the contention that plyometric are dangerous or that a minimal level of strength is needed to perform low- to moderate-intensity plyometric actions" (Faigenbaum et al., 2009). Studies examining youth plyometric training have shown it to be safe and effective for performance improvements

[2] S&C means Strength training and conditioning and it is an adapted term to include several modalities of exercise.

(Diallo, Dore, Duche, & Van Praagh, 2001; Faigenbaum et a., 2009). Youth plyometrics training enhances jumping ability, running time, pushup performance, and speed (Diallo et al., 2001; Faigenbaum et al., 2009; Kotsamidis, 2006), and these improvments have occurred beyond the changes that are associated with typical activity experienced in physical education classes (Kotsamidis, 2006). Medicine ball training is productive in children and adolescents (Faigenbaum et a., 2007; Faigenbaum et al., 2009; Mediate & Faigenbaum, 2007). Marginson et al. (2005) showed that "a plyometric workout resulted in mild post-exercise soreness (compared to adult men) but repeated exposure limited muscle damage and dysfunction in children" (Marginson, Rowlands, Gleeson, & Eston, 2005). Research demonstrates that plyometric training (PT) results in power and strength gains in adolescent athletes (Faigenbaum et al., 2007; Myer, Ford, Brent, & Hewett, 2006), and that PT may in fact contribute to increased bone mineral content in young females (Witzke & Snow, 2000). Comparing to adults, Children and adolescents respond more favorably to plyometrics training in relation to soreness responses after exercise. However, "it may not be prudent for youths to perform high-intensity drills such as depth jumps but these exercises represent only a myriad of the number of plyometric exercises young athletes can perform. Youth plyometric training programs should begin with low-intensity drills where proper form and technique are stressed. A gradual progression to moderate-intensity drills should be used where the major goals are to increase youth fitness, balance and coordination, and performance" (Siff, 2000). literutre did not point out an appropriate minimal age for stating a plyometrics training program but some S&C professionals have had success training children 7–8 years of age provided "they have the emotional maturity to listen to instructions and perform the exercises properly" (Potash and Chu, 2008a). Permitting a childor adolescent to enroll in plyometrics training is decision should be taken by parents or coach as it is safe and efficient when properly supervised. An appropriately designed PT program could better prepare young athletes for the demands of sport practice and competition by enhancing neuromuscular control and performance. As with adults, recovery between workouts must be adequate to prevent overtraining. Optimal amount of recovery should vary based on the intensity of the training program and the participant's skills, abilities, and tolerance as well as on the same time of year (e.g. off-season, pre-season, or in-season) (Potash and Chu, 2008a).

2.1.7 Designing a Plyometric Program

Plyometrics training, like other modes, is a compound of some acute program variables that can be manipulated to reach the goal. These variables include exercise selection and order, intensity, volume, frequency, and rest intervals. Designing a plyometric training program for athletes is multifactorial and should include planned progressive overload, specificity, and variation (Siff, 2000).

To administer a land-based plyometric training (PT) program, many factors need to be implemented including the age, athletic maturity, experience, training status of the athlete, equipment availability, training surface, and recovery in between workouts, nutrition, mode, and the integration of plyometrics with other training Modes" (Chu, 1998; Potash & Chu, 2008b; Ratamess, 2012). However, most plyometrics training literuture are not comparative. A wide variation of programs are efficient for enhancing performance but few literature compared changes when manipulating program variables.

Thus, plyometric guidelines available depend mostly upon the practical experience of coaches with a little therotical support. Other criticals to plyometrics training include the following:

Development of a plyometric program should begin with establishing an adequate strength base that will allow the body to withstand the large stresses during ground contact (Voight & Tippett, 2004)

• The quality of training is most critical. Each repetition should be excuted with maximal physical stress, minimal amortization and coupling times, and explosive propulsion.

• Selection of the exercise should be as specific to the reqirments of the sport as possible. Sport-specific exercise could be included within plyometrics exercises to improve skill development along with power. "It is critical for the coach to address limb and rotational dominance in athletes" (Verkhoshansky & Siff, 2009). Unilateral exercise are significant for athletes that, in part, excute explosively with one leg or arm during propulsion. Bilateral exercise are critical for athletes involved in sports need bilateral limb power. Many sports includ both. So plyometrica training programs in these athletes should consists of uni and bilateral rxercise. For example, "a right-handed baseball pitcher needs to explosively push off with the right leg against the rubber on the mound and produce high total-body power during counterclockwise rotation during the wind-up, delivery, and follow-through phases of pitching. Thus, single-leg push-offs and lateral hops, as well as counterclockwise MB tosses and throws, can be used to train these actions" (Siff, 2000)..

• Gradual progress should be planned depending upon the athlete's training level. Progress involves increases in intensity by addimg more complex drills and perhaps some external resistance. Volume can be increased within logical limits. Also, volume and intensity are related inversely. Low-intensity and moderate-intensity exercise should be controlled before progressing to high-intensity drills. It has been suggested that "athletes have at least a few years of RT and plyometric training experience prior to performing maximal depth jump training" (Verkhoshansky & Siff, 2009). High intensity workouts need longer recovery time among workouts. So, frequency should be decreased accordingly.

• "Proper technique should always be coached especially when fatigue manifests. Sufficient rest interval lengths should be used to minimize fatigue when peak power is the goal (and not power endurance)" (Siff, 2000).

• "Plyometric training should take place in an area where there is sufficient space. For horizontal length-specific drills, at least 30–40 yd is recommended. For vertical drills, ceiling height should be higher than the athletes' maximal reach" (Siff, 2000).

2.1.7.1 Mode and Exercise Selection

Plyometric drills include mostly "jumps in-place, standing jumps, multiple hops or jumps, bounding, box drills, depth jumps, and throws" (Chu, 1998; Radcliffe & Farentions, 1999). Depending upon the body region or major muscle group(s) involved in a specific code-of-sport. These drills could be classified into lower body plyometric, upper body plyometric, and trunk plyometric drills. Sport-specific movement patterns and activities can involve both the upper and lower body.

- **Lower body**

Lower body plyometric are appropriate for virtually any athlete and any sport. Lower body PT allows the participant the ability to produce more force in a shorter amount of time, thereby allowing a higher jump. Depending upon the requirements of the sport, a participant must be able to produce quick and/ or repeated powerful movements and changes in direction in all planes: horizontal, vertical, and lateral (Potash & Chu, 2008b).

Jumps include maximizing the vertical and/or horizontal motion component. Hops include maximizing the repeated motion for a distance or pattern. Bounds are exaggerated horizontal movements where an excessive stride length is utilized. Box drills include jumping on or off boxes of various sizes for varied intensity. Depth jumps include emphasizing the ECC component by stepping off of a box of differnt height prior to excuting an explosive jump. Tosses and passes include the upper torso and arms (in addition to lower body and core power) releasing the ball or object below or in front of the head. Throws include the upper torso and arms (in addition to lower body and core power) releasing the ball or object above, over, or across the head. It should be noted that all these drills are excuted explosively with minimal amortization and coupling phases. "Some drills can be combined to form a more complex drill, i.e., adding a sprint or multidirectional hop/jump to a depth jump. In addition, ballistic exercises are plyometric due to the release of the load (minimizing deceleration)" (Siff, 2000). Table 1 describes these different types of lower body drills.

Table 1. The different types of lower-body plyometric drills

Type of Jump	Rationale
Jumps in Place	These drills involve jumping and landing in the same spot. Jumps in place emphasize the vertical component of jumping. They are usually performed repeatedly without rest between jumps
Standing Jumps	Standing jumps emphasize either the horizontal or vertical components. These drills are at maximal effort with sufficient recovery between repetitions.
Multiple hops and jumps	These drills involve repeated movements and may be viewed as a combination of jumps in place and standing jumps.
Bounds	These drills use exaggerated movements with greater horizontal speed than other drills.
Box Drills	By using a box these drills increase the intensity of multiple hops and jumps. The box may be used to be jumped on to, or jumped off from.
Depth Jumps	Using the athlete's gravity, depth jumps increase exercise intensity. The athlete assumes a position on a box, steps off, lands, and immediately jumps vertically, horizontally, or to another box.

Note. From (Potash & Chu, 2008b)

- **Upper-body plyometric**

Rapid, powerful upper body movements are required for several sports and activities (Potash & Chu, 2008b). Plyometric drills for the upper body are not used as extensively as the lower body, but they are nevertheless essential to athletes who require upper body power (Newton et al., 1997; Wilk et a., 1993). Stretch shortening exercises for the throwing athlete provide advanced strengthening exercises that are more aggressive and at higher exercise levels (higher demands on shoulder musculature) than those provided by a simple isotonic dumbbell exercise program. These programs can only be utilized once the participant has performed a strengthening program for an extended period of time (Wilk et al., 1993). Plyometric for the upper body include, amongst other, medicine ball throws, catches, and several types of push-ups (Potash & Chu, 2008b).

- **Trunk plyometric**

The trunk has an equally significant role in athletic movements. In addition to controlling posture, the trunk serves as the vital link for the transference of forces from the lower body to the upper body. This forces transfer is a common occurrence and necessary in throwing and racquet sports (Voight et al., 1995). Exercises for the trunk can also be performed "plyometrically", as it is difficult to perform true plyometric drills to utilize the stretch shortening cycle directly target the trunk musculature (Potash & Chu, 2008). Use of medicine balls has offered new dimensions to trunk plyometric, for explosive power development in both flexion and rotation, safely and effectively (Boyle, 2004).

"Exercises such as the jump squat, bench press throw, ballistic leg press, and ballistic shoulder press target the SSC and increase power. It is advantageous to use equipment designed to safely catch the weight via hydraulic braking when released. See below discussion about safety considerations" (Siff, 2000).

2.1.7.2 Intensity

Intensity is the effort involved performing a given task (Chu, 1998), and also the amount of stress placed on involved muscles, connective tissues, and joints and is primarily controlled by the type of plyometric exercise performed (Potash and Chu, 2008a). The intensity of plyometrics drills rely on some factors including "the exercise complexity, loading, speed, and the size and length of boxes or barriers used" (Siff, 2000). Plyometric range from simple tasks to highly complex and stressful exercises. Low intensity exercises that are long response in nature (more than 10- repetitions), place high demands on the anaerobic glycolysis energy system. High intensity exercises are short response in nature (less than 10-repetitions), place high demands on the ATP-CP energy system (Piper & Erdmann, 1998; Radcliffe & Farentions, 1999).

Depending upon to the kind of drill utilized, "Jumps-in- place are lowest in intensity, followed by standing jumps, multiple hops and jumps, bounding, and box drills" (Chu, 1996, 1998). Depth jumps are the most intense kind of plyometrics drills. Greater loading during landing increases the intensity of the plyometrics drill. Loading increases when the mass of the body increases (from external loading with weighted vests or weights) and when the velocity of impact increases (from upper jump heights). Intensity of plyometrics drills could be increased by progressing single leg jumps which are more intense than comparable double leg jumps, and can be also increased by simply aiming to cover a further distance in longitudinal jumps (Chmielewski et al., 2006; Chu, 1998). The intensity of plyometrics drills could be increased by adding a low to moderate amount of external loading. "For example, using a weighted vest, MB, dumbbells, or other loading device can increase the intensity of plyometric training" (Siff, 2000).

Also, "the athlete's body weight plays a role as one plyometric drill may be more intense in an athlete of greater size than a smaller athlete. Intensity is increased by using larger barriers or boxes, or by setting cones/barriers further apart. This requires the athlete to jump higher or further per repetition" (Siff, 2000).

Horizontal body movements are less stressful than vertical movements, depending upon the participant's technical proficiency and body mass. The heavier the participant, the greater the training demand placed on the participant (Voight & Tippett, 2004). Intensity of upper extremity plyometric exercises can be increased by using heavier resistance, moving the body or ball through greater distances, using higher speeds, and finally progressing from double-arm to single-arm activities (Chmielewski et al., 2006). In general, as intensity increases, volume should decrease. Consideration must be given to choosing the right drills for the sport during a specific training cycle (e.g, off-season, pre-season, or in-season) (Potash & Chu, 2008). When performing high intensity exercises, proper technique is the primary objective. Volume-based parameters must be modified if technique deteriorates (Piper & Erdmann, 1998).

programs Plyometric training starts with low and moderate intensity drills and progresses to higher intensity drills over time. Thus, plyometric exercise prescription is a common method to alter training intensity. Table 2 demonstrates a range of plyometric execises based on intensity. Low, moderate, and high intensity classifications are utilized. It should note that any exercise listed (including low intensity drills) can be made more intense by methods previously described.

Table 2. Plyometric exercise intensity continuum

Low intensity	Moderate intensity	High intensity
Pogoes	Barrier jumps	Pike jump
Side-to-side ankle hop	Tuck jumps	Single-leg vertical jump
Jump and reach	Split squat jump	Single leg hops
Squat jump	Double leg hops	Depth Plyo push-up
Standing long jump	Box jumps	MB power drop
Cone hops	Alternate bounding	Single leg bounding
Single-leg box jump	Single-arm vertical CB throw	Depth jump and variations
Skipping	Plyo push-up	
MB chest pass	Triple jump	
Overhead MB throw	Multiple box jumps	
MB back throw		
Overhead MB slam		
MB underhand throw		
Pullover pass		
MB side throw		
MB front rotation throw		
Bag thrusts		

Note. MB= Medicine Ball, CB= Core Ball, Core Balls are MBs with handles to facilitate better gripping. From (Ratamess, 2012)

2.1.7.3 Exercise Order

As opposed to Resistance Training, there are basically no sequencing advices for plyometric exercises. Plyometric exercises can be sequenced in numerous ways However, most sequencing patterns could be advantageous provided sufficient recovery is given among sets and exercises. Low intensity exercises could be inserted anywhere in sequence. Many coaches prefer to insert one or two at the beginning of a workout to help for better warm up or to prepare athletes for subsequent high intensity exercise. Low intensity exercies culd be excuted later in the workout after other significant moderate and high intensity exercises are excuted. Moderate and high intensity exercises are typically excuted near the beginning (following proper warm-up and low intensity exercises) while fatigue is minimal and energy levels are high. Because the intensity level is greater, it is most advanagous to excute these exercises early to maximize SSC activity. When upper body plyometric exercises are involved, the athlete may select to alternate between lower and upper body exercises (similar to resistance training). It should provide greater recovery in among exercises. Upper body plyometric exercises can be inserted among lower body exercises to maximize workout productivity without compromising SSC performance. Lastly, "plyometric exercises may be incorporated into an RT workout (known as complex training)" (Chu, 1996, 1998). A technically similar plyometric drills can be executed among sets of a similar resistance exercise. "Some sample pairings may include performing squat jumps in between the sets of barbell back squats, tuck jumps in between sets of front squats, box jumps in between sets of hang cleans, an MB chest pass in between sets of the bench press, and bag thrusts (or striking a heavy bag) in between sets of ISOM wall pushes or the close-grip bench press. Post-activation potentiation occurs during the performance of plyometric drills after resistance exercises. Acute power enhancement may be augmented when using complex training" (Siff, 2000).

Although research shows that complex training acutely enhances athletic power (Santos & Janeira, 2008), "short-term training studies have not shown complex training to be more effective for enhancing power or vertical jump performance to a greater degree than performing plyometric and RT separately" (Mihalik, Libby, Battaglini, & McMurray, 2008). So, merging plyometric drills into a resistance training workout is effective for imroving power as separate workouts.

2.1.7.4 Lower body Volume

Plyometric volume is the total work performed during a single training session, expressed as the number of repetitions and sets (Chu, 1998; Potash and Chu, 2008a) and rely on training intensity and frequency in addition to the impact of other training modes. For lower body plyometric, the number of foot contacts, each time a foot, or feet together, contact the surface per workout, but can be expressed as distance covered with bounding (Chu, 1998). Recommended volume of foot contacts in any one-session will vary inversely with the intensity of the exercise (Voight & Tippett, 2004). In a review of plyometric literature, Coetzee (2007) summarized that plyometric volume can amount to between 1 and 10 exercises, and range between 2 and 10 sets (Coetzee, 2007).

Suggested lower body plyometric volumes vary for participants of different levels of experience. Suggested plyometric volume guidelines are indicated by foot contacts per session: beginners (no experience) 80- to 100-; intermediate participants (some experience) 100- to 120- and advanced participants (considerable experience) 120- to 140-foot contacts (Coetzee, 2007; Potash & Chu, 2008a).

For upper body or core plyometric, the number or repetitions of throws, catches, passes, or tosses per training session represents training volume (Potash & Chu, 2008b; Ratamess, 2012). Similar to other methods of exercise, plyometric volume and intensity are related inversely. Some guidelines fore plyometric training volume are available. Chu (Chu, 1998) has recommended some guidelines for plyometric training that are listed in Table 3.

Table 3. “Plyometric training volumes based on experience [a]

Status	Off-season	Pre-season	In-season
Beginner	60–100	100–250	Depends on Sport
Intermediate	100–150	150–300	Depends on Sport
Advanced	120–200	150–450	Depends on Sport

Note. a= Numbers represent foot contacts per workout. Warm-up exercises are not included. The wide range of values during preseason indicates variations in intensity. That is, high-intensity drills yield lower volumes whereas low- and moderate-intensity drills yield higher volumes. In-season volume depends on the sport as volume will be low in sports that are highly plyometric in nature”. Adapted from Chu DA (Chu, 1998).

2.1.7.5 Frequency

Frequency refers to the number of plyometric training sessions per week and usually ranges between two to four times a week (Coetzee, 2007), depending on the sport and time of the year (Potash and Chu, 2008a). Duration of the PT programs vary between three and 12-weeks (Coetzee, 2007) . Generally, 48- to 72-hours of rest is recommended for recovery between plyometric training sessions (Chu, 1998).

Training frequency relies upon other variables such as intensity and volumein addition to the inclusion of other training Modes. However, Intensity plays a major role in determining the frequency of training (Voight & Tippett, 2004). High intensity training may demands a lower frequency especially when depth jumps are excuted, and frequency may be lower jumps are executed, and frequency may be lower when other methods are involved. In-season training of athletes needs a low training frequency. Sport practices and competitions consist of plyometric movements so that training must be improved around the intensity and volume of plyometric movements seen in the sport. So, keping plyometric training of 1–2 days per week may be enough which could balance any potential detraining effects.

"Because of the intense nature of plyometric training, ~48–72 hours of recovery in between training sessions is recommended" (Chu, 1998; Potash & Chu, 2008a). Few frequency comparative studies have been conducted. de Villarreal et al. (2008) showed that "1 day per week and 2 days per week (with double the number of drop jumps) frequencies produced greater improvements in vertical jump and sprinting speed than high-frequency (4 days per week with quadruple the number of drop jumps) training" (De Villarreal, Gonzalez-Badillo, & Izquierdo, 2008). So, coach should try his best in planing plyometric training frequencies. Similar to resistance training, it is the intensity and volume that may be the significant variables provided that the frequency choosed allows adequate recovery time among workouts.

2.1.7.6 Rest Intervals

Recovery is defined as the rest time between repetitions, sets, or sessions of plyometric exercise (Chmielewski et al., 2006). Plyometric exercises is critical for training adaptations. Recovery is the key variable determining whether plyometric will develop power or muscular endurance. Adequate rest intervals are required when maximizing power is the goal. If an adequate recovery period does not occur, muscle fatigue will result in the participant being unable to respond optimally to the exercise stimuli (ground contact, distance, height) with maximal quality efforts (Chu, 1998; Voight & Tippett, 2004)(Chu, 1998; Voight & Tippett, 2004).

Recovery between exercises will vary from one athlete to another depending on skill and fitness level (Piper & Erdmann, 1998). Work-rest ratio for a plyometric exercise depends on the intensity of the exercise and the energy system used. In general, the higher the intensity, the longer the recovery time required if the goal is to stress the ATP-PC energy system. If muscle endurance is a goal, short rest periods can be employed (Piper & Erdmann, 1998). For power training, a longer recovery of 45- to 60-seconds between sets of multiple of events, allow for maximum recovery between efforts (Chu, 1998). A work-rest ratio of 1:5 to 1:10 is recommended to ensure enough rest for proper execution of the exercise (Chu, 1998; Coetzee, 2007). Shorter recovery periods of 10-15 seconds between sets do not allow for maximum recovery of muscular endurance, since PT is an anaerobic activity (Chu, 1998). For example, when performing a maximum-effort drop vertical jump, athletes may rest for 5- to 10- seconds in between repetitions. In rehabilitation settings, where low-intensity plyometric exercises are often used, smaller work-rest ratios (e.g., 1:1 or 1:2) have been used (Voight & Tippett, 2004). Allowing proper recovery time ensures that sufficient muscle force is available for the optimal performance of plyometric exercise (Chmielewski et al., 2006).

For non-continuous or single repetition jumps (depth jump) or throws, intra-set rest intervals are useful for maximizing power. For example, Potash & Chu 2008 suggested "5–10 seconds of rest in between submaximal depth jumps is recommended with 2–3 minutes of rest in between sets" (Potash and Chu, 2008b).

However, "maximal depth jumps require longer intra-set (up to 2–4 min) and inter-set (>5–10 min) rest intervals" (Verkhoshansky & Siff, 2009). Rest interval lengths are drill-specific and rely on the intensity. More recovery may be required among sets for high intensity drills than low or moderate intensity drills. For example, "a 30-second rest interval between sets of ankle hops is sufficient but maybe not sufficient when performing sets of box jumps. Work-to-rest ratios of 1:5–1:10 are recommended" (Chu, 1998; Potash and Chu, 2008a). "Using a 1:10 ratio, an athlete would rest ∼100 seconds if the total set length was 10 seconds. Thus, 1:5 ratio may be applied to low- and moderate-intensity drills and 1:10 ratio to when other modes are included.

2.1.8 Other considerations in plyometric program design

Designing plyometric training programs depends on additional factors. Potash and Chu (2008) advised that plyometric is a form of resistance training and therefore must follow the principles of progressive overload, and must follow the systematic increase in training frequency, volume and intensity in various combinations. The sport and training phase will determine the training schedule and method of progressive overload. Generally, as intensity increases, volume decreases. The PT program's intensity should progress from low to moderate volumes of low intensity, from low to moderate volumes of moderate intensity, from low to moderate volumes of moderate to high intensity. As in any program, plyometric exercise should be preceded with a general warm-up, dynamic stretching, and a specific warm-up. Other considerations for designing a plyometric program include the warm-up, age, training status, surface, and equipment availability.

2.1.8.1 Warm-up

Any plyometric training program should commence with an adequate warm up. A general warm-up may be used initially (5–10 min of jogging) followed by a specific warm-up. The specific warm up must include low intensity, dynamic movements (Potash and Chu, 2008a). The specific warm up drills choosed are utilized to prepare physiologically the athlete for the workout. They are utilized to enhane key movement skills and coordination transferable to plyometric training. Drills are low in intensity. Some examples of good plyometric training warm up drills include "marching, high knees, butt kicks, skipping, lunges, back pedaling, side shuffles, cariocas, and progressive form running. These drills are commonly used in preparation for sprint and agility training" (Siff, 2000). Table 4 demonstrates these various kinds of lower body plyometric warm up drills. "The warm-up can consist of 10–20-m length drills where the athlete performs the set, rests, and returns back for a second set, or performs a set up and walks back to increase recovery in between sets. If a group of athletes are warming-up together, each athlete can rest a few seconds more while another squad is performing the drill. At least 10 total sets are performed (1–3 sets per drill)" (Siff, 2000).

Table 4. Lower-body plyometric warm-up drills

Type of Jump	Explanation
Marching	Mimics running movements. Improves proper lower body movements for running.
Jogging	Prepares for impact and high-intensity plyometric drills. E.g. toe jogging, straight-leg jogging, butt-kicking.
Skipping	Skipping is an exaggerated form of reciprocal upper and lower extremity movements.
Footwork	Footwork drills that target change of direction.
Lunging	This drill is based upon the forward lunge, and may also be multi-directional.

Note. From (Potash & Chu, 2008)

2.1.8.2 Age

The majority of literuture of plyometric training has emphasized on young adults and adults typically in their 20s and 30s. However, the use of plyometrics exercise in children, adolescents, and middle aged to older adults has received some attention, and in some cases scrutiny. Part of the issue dealing with plyometric training in these populations has been the different terminology in describing plyometric. Some view plyometric in classic terminology as predominantly depth jumping at high levels of intensity. In contrast, many view plyometric in modern terminology as drills that stress the SSC which vary extremely in intensity. modern plyometric literature may recommended that plyometric can be advantagous for most individuals regardless of age. Plyometric drills vary in intensity and many low intensity drills are appropriate for many populations. Plyometrics training could be safe and productive for individuals regardless of age when correctly administered.

“Plyometric exercises can benefit middle-age and older adults. Muscular power deteriorates at a faster rate than strength with aging and attempts to maintain or improve power can be beneficial to improving fitness. Part of the perception in society is that plyometric exercises are more reserved for young adults. However, plyometric actions are commonly performed in middle-age and older adults who frequently play pick-up games of basketball or racquetball for example” (Siff, 2000). elite athletes utilizes extremely plyometric training. Attention must be paid regarding potential orthopedic limitations and plyometric may be contraindicated for some. “Plyometric training guidelines for adults may be used for masters athletes with the exception that volume may be lower and low- to moderate-intensity drills are preferred" (Potash and Chu, 2008a).

2.1.8.3 Training Status

In designing a Plyometric training program, the training status of the athlete should be conseration. Novice athletes should starts with a basic program included low intensity exercises and progress to high intensity ones gradually over time as conditioning and coordination improve. Trained athletes have greater tolerance and can execute higher intensity and volume exercises. "In the past, the strength level of the athlete was considered within the training status domain. Early European coaches recommended that athletes needed to have great strength, e.g., able to squat at least 1.5–2.5 times their body weight and have high levels of ECC and explosive ISOM strength, before beginning plyometric training" (Verkhoshansky & Siff, 2009). These guidelines were never intended to apply to submaximal plyometric exercises. If this were the case, few athletes would qualify and this suggestion no longer is relevant for several plyometric exercises. "These early suggestions were made due to the fact that depth jumping comprised classic plyometric and impact forces could exceed six times the athlete's body weight" (Verkhoshansky & Siff, 2009). It is not logical to obligate an athlete to have high levels of strength in order to start a program including basic vertical jumps or pogoes. Others have recommended that "athletes be able to squat 1.5 times their body weight, bench press their body weight (for heavy athletes) or 1.5 times their body weight (for athletes who weigh less than 220 lb), perform five plyo push-ups in a row, and be able to perform speed squats and bench presses (5 repetitions in less than 5 s with 60% of body weight)" (Potash and Chu, 2008a). These standards are used mostly to high intensity exercises. Some coaches have utilized balance or stability estimation prior to enroll in plyometric training. A coach could utilize periodic assesment of their athletes to determine if that athlete is ready to go more intense exercise. "Although it may be helpful for an athlete to have a solid strength foundation (especially adequate ECC strength), other fitness components are critical including balance, coordination, power, speed, and agility. Because plyometric training helps improve all of these fitness components, an athlete of lesser conditioning and strength can greatly benefit from plyometric training but mostly via low- to moderate-intensity drills" (Siff, 2000).

2.1.8.4 Training Surface

Plyometrics training could be conducted in a various places. The surface choosed should be yielding and could decrese the overall joint stress to the body. However, the surface should not be too yielding. Impellizzeri et al. (2008) reported 4 weeks of plyometric training on grass and sand increased jumping and sprint performance. However, grass produced superior results while less soreness was shown after plyometric training in the sand (Impellizzeri, Rampinini, Castagna, & Al, 2008). Grass is a popular option for plyometric exercise as open fields have the advantage of enabling longer distance exercise to be executed. "Matted floors and gymnastics floors are acceptable training surfaces. The mats cannot be too thick as this can excessively increase the amortization phase" (Potash and Chu, 2008a) and not maximize the SSC. Concrete and hardwood floors lack the shock absorbing ability and may cause excessive strai. A few studies have examined the potential of aquatic plyometric training.

Water training has a benefit of increasing resistance during jumping and depending upon the depth of the water. But it has a disadvantage of minimizing ECC loading due to the buoyancy of the water. Stemm and Jacobson 2005 and Martel 2007 showed that "aquatic plyometric training increased vertical jump" (Martel, Harmer, Logan, & Parker, 2005; Stemm & Jacobson, 2007). Thus, "aquatic plyometric training can be effective especially for single-leg exercises" (Verkhoshansky & Siff, 2009). Lastly, "the level of inclination or declination in the surface is important. Many times plyometric training will take place on a relatively even surface. However, surface angular alterations can pose a new stimulus for training" (Siff, 2000).

Uphill Plyometrics training enhances the metabolic and force requirements requirement whereas downhill plyometric training enhances the ECC component, intensity, and results in greater post exercise muscle soreness.

2.1.8.5 Plyometric Training Equipment

Plyometric training could be conducted without any specialized equipment. "However, some pieces of equipment may be needed in order to perform some drills. Some common pieces of equipment include cones, boxes, jump ropes, mini hurdles, bands, bags, weighted vests, MBs, slam balls, and core balls. Cones can be used as barriers or guides, or can be used as obstacles for various hops and jumps. Cones usually range in size from small (4.5 in.) to large (18 in.). Boxes are used for box jumps, depth jumps, and variations. Plyo-boxes come in various sizes but must be sturdy to offset the explosive nature of plyometric exercises. Many boxes will be made of wood or tubular steel capable of withstanding large levels of force. Boxes come in various sizes from small (~6 in.) to large (~42 in. or greater). Smaller boxes are used for hops with larger boxes used for box jumps and depth jumps. Important to box selection is the upper surface" (Siff, 2000).

The box top surface should be made of nonskid rubber for greater friction and stability upon landing. "The surface dimensions may range from 14 × 14 in. for smaller boxes to 20 × 20 in. for larger boxes. Some smaller boxes have added utilities. There are angled boxes with multiple surfaces that allow for lateral plyometric exercises" (Siff, 2000).

Jump ropes come in various forms and sizes with some designed more for speed and some to provide some resistance.

Hurdles serve as obstacles for hops and jumps. Hurdles usually range from 6 to 12 in. up to 42 in. or higher. Some hurdles could be adjustable which can be utilized for multiple drills.

"Bands provide resistance to jumping. Several styles are currently on the market. One particular resisted jump training device is the Vertimax. The Vertimax consists of a matted platform with resistance bands attached to a waist harness that gives the athlete resistance during several types of jumps. The loading from the bands creates greater ECC loading upon landing which serves as a potent stimulus for plyometric training. Several studies have examined jump training with the Vertimax" (Siff, 2000). Rhea et al reported that "12 weeks of training with the Vertimax produced superior increases in vertical jump height and power in athletes than unloaded plyometric training" (Rhea, Peterson, Lunt, & Ayllon, 2008; Rhea, Peterson, Oliverson, Ayllon, & Potenziano, 2008). However, McClenton et al. suggestes that "6 weeks of depth jump training versus jump training on the Vertimax produced similar increases in performance" (McClenton, Brown, Coburn, & Kersey, 2008), Carlson et al. suggested also that "6 weeks of jump training on the Vertimax was no more effective than RT or plyometric training for increasing jump performance" (Carlson, Magnusen, & Walters, 2009). "Nevertheless, jump training on the Vertimax is effective for enhancing jump performance. Weighted vests can be used for additional resistance during plyometric drills. Various vests are available but typically allow external loading of up to 30 lb or more but caution must be used as external loading may be most appropriate for low- and moderate-intensity drills. Bags (boxing, football) can be used as obstacles for jumping over. Medicine, core, and slam balls come in various sizes and are used for upper and lower-body plyometric" " (Siff, 2000).

2.1.8.6 Plyometric and Safety Considerations

"Plyometric training is safe for athletes of all ages provided that common sense is used in the program design and it is properly supervised" " (Siff, 2000). The most common reasons for injuries during plyometric training are: "(a) violation of training guidelines, (b) inadequate warm-up, (c) too high a rate of progression, (d) lack of skill, (e) poor surface selection, (f) improper volume or intensity, and (g) undisclosed predisposition" (Potash and Chu, 2008a). Violations of training guidelines, coupled with high volume with too high intensity may lead to overreaching and overtraining. Overtrained athlete is more susceptible to injury. In plyometric training, the quality of the workout is more important than quantity especially when depth jumps are excecuted. Volume and frequency shoule planned carefully depending upon the training phase. Inadequate warm ups force the athlete to go to intense, explosive muscle contractions without correct physiologic preparation thereby increasing the risk of injury.

"Lack of skill is a particular problem for coaches and athletes. Poor technique among athletes may limit exercise selection. Sufficient coordination, balance, and strength are needed for performance of several plyometric exercises including those moderate to high in intensity" " (Siff, 2000).

Coach should emphasizes on the correct jumping technique with athletes at all phases of training. Critical to correct jump technique is the landing where greater levels of force are absorbed by the athlete's body. Peak impact forces during jumping could be greater than the peak propulsion forces. Incorrect landing can place the athlete at greater risk of injury. Plyometric exercises range in complexity. starting exercises may included in the entire workout for poorly fit athletes. An athlete requires to have improvement in his technique plus to increase his neuromuscular conditioning before to progress toward more difficult exercises. Attention should be paied to athletes of larger massive bodies. Larger body place greater loading to musculoskeletal system thereby increasing the risk of injury if not careful. "The volume of plyometric training should be lower for large athletes and the intensity must closely be monitored' (Potash and Chu, 2008a). It has been suggested that "large athletes not perform depth jumps off of boxes greater than 18 in." (Potash and Chu, 2008a). if an athlete has not previously injured, Plyometric training is safe. A prior injury could make a greater risk to the athlete. "Careful monitoring of the athletes is necessary. An injury may necessitate altering or temporarily discontinuing plyometric training until medical clearance has been attained. Lastly, proper breathing during plyometric is important. Similar to high-intensity RT, a Valsalva maneuver is typically used during the ECC and early CON phases of the drill to ensure proper stability, shock absorption, and force and power production during propulsion. Exhalation ensures shortly afterward during the latter stages of the CON action" " (Siff, 2000).

2.1.9 Integrating plyometric with other training modes

Plyometrics training is usually performed with other methods of training during a training periodization to produce maximum results of the athletic performance. Plyometrics and resistance training could be included simultaneously within A program. For example, "plyometric training 2 days per week can easily be incorporated into an RT program. Plyometric training can be performed on off-lifting days or on the same day. If performed on the same day, plyometric training may be given priority and performed first. Resistance training can be performed after or later in the day. The muscle groups trained for each workout is important. If only the upper body is resistance trained that day, then lower-body plyometric can be performed uninhibited and the sequence can vary" (Siff, 2000).

It is not recommended that high intensity lower body resistance training and lower body plyometric training be executed in the same day as the mode-trained second would do so in a semi fatigued state. Plyometric exesrcises coule also be integrated into a weight training workout, e.g., complex training.

Plyometrics training should coincide with sprint and agility exercises so that productive integrated programs could be developed. These training methods simulate physiological mechanisms and work to optimize neuromuscular performance so integration of these methods into a workout is common. Plyometrics, sprint, and agility exercises could be changed or be in sequence within a workout. In some sports, an athlete requires a good aerobic fitness. So, aerobic training may be executed along with plyometric. It should detrmine that an incompatibility exists between high intensity anaerobic and aerobic training methodes. However, low to moderate levels of aerobic training should be executed without compromising performance. So, it is recommended that plyometric training be executed first then followed by aerobic exercise. Flexibility exercise should be performed at the end of a plyometric workout and not before.

2.1.10 Incorporation

In designing a plyometric program, all factors discussed above should integrated. many productive programs could be developed provided that the progressive overloading, specificity, and variation are utilized correctly and the program is supervised very well. The significant elements are selecting sport-related drills and palnning appropriate levels of intensity and volume. Each repetition should be executed explosively and coach should constantly monitor technique and emphasizes on proper and correct mechanics to his athlete.

2.2 Review of Related literature

The related literature were selected from studies of the last five years to be in touch with the new literature. Earlier studies were included in theoretical literature.

In study of Hunnicutt, Elder, Dawes, & Elder (2016), Plyometric training has been implemented to increase jump height in a variety of sports, but its effects have not been researched in figure skating. The purpose of this study was to determine the effects of a plyometric training program on on-ice and off-ice jump performance. Six collegiate figure skaters (19.8±1.2 years; 164.7±4.9 cm; 60.3±11.6 kg) completed a six-week sport-specific plyometric training program, consisting of low to moderate intensity plyometric exercises, while eight collegiate figure skaters (21.1±3.9 years; 162.6±6.0 cm; 60.4±6.1 kg) served as the control group. Significant increases were found for vertical jump height, standing long jump distance ($F = 31.0$, $p < 0.001$), and flight time ($F = 11.6$, $p = 0.007$). No significant differences were found for self-reported jump evaluation ($p = 0.101$). Six weeks of plyometric training improved both on-ice and off-ice jump performance in collegiate figure skaters, while short-term skating training alone resulted in decreases. These results indicate that figure skaters could participate in off-ice plyometric training (Hunnicutt, Elder, Dawes, & Elder, 2016).

In study of Ozbar (2015), The aim was to examine how to speed, explosive strength, and kicking speed are affected by a 10-week plyometric training (PT) program in elite female soccer players. Twenty adult players from Women First League (age=19.3±1.6year, height=163.3±4.7cm, body mass=56.6±6.1kg) were divided into plyometric group (PG) and control group (CG). Both the groups performed technical and tactical training and matches together. PG performed PT 2 times per week for 10 weeks. No significant difference was found between the groups at pretest variable ($p>0.05$). The significant improvement was found in the posttest of both groups ($p<0.05$), except for 10-20-m sprint test in the CG ($p>0.05$). Sprint, counter movement jump, standing broad jump, peak power and kicking speed test values were all significantly improved in the PG, as compared with the CG ($p<0.05$). The results indicated that safe and effective PT can be useful to strength and conditioning for explosive strength (Ozbar, 2015).

In study of Natha & Kumar (2015), The purpose was to determine the effect of 8 weeks plyometric training on the selected motor abilities namely speed, explosive strength and agility of the male jumpers. For the purpose of the study 50 male long jumpers in the age range of 17-30 years were selected from different coaching centers of Delhi who were further randomly divided into two equal groups (25 each in experimental group and control group). The experimental group underwent plyometric training twice a week for 8 weeks with each session consisting of 30-45 minutes duration with additional warm up time. A week schedule was repeated to the preceding week and the load was adjusted progressively by 10%. The control group was not allowed to take part in the specific experimental training except their daily general warming up and normal activities. The 40m sprint test, standing broad jump and shuttle run test (10× 4) were the criterion measure for speed, explosive strength and agility of the male jumpers which were employed before and after the training (Pre Test and Post Test). Analysis of Covariance was employed as the statistical tool for the study. The findings of the study showed a significant difference in the speed and explosive strength of the experimental group (6.90 sec and 2.61 m) and control group (7.06 sec and 2.51 m) as the adjusted posttest means obtained were 4.305 and 8.22 $p \leq 0.05$ (Natha & Kumar, 2015).

In study of Lehnert, Hůlka, Malý, Fohler, & Zahálka (2013), Explosive strength of the lower extremities and agility are important parts of game performance in basketball. Although numerous studies have focused on the assessment of the training effect of plyometric training, studies focusing on elite players are missing. The aim of the study was to find out what changes in explosive strength of the lower extremities take place after a 6 week plyometric training applied in training units during the pre-season in elite basketball players. Elite basketball players (N = 12, age 24.36 ± 3.9 years, height 196.2 ± 9.6 cm, weight 92.9 ± 13.9 kg) performed a 6 week plyometric training (PT) program predominantly focused on explosive strength of the lower body and upper body and was conducted in sixteen training units during pre-season. The changes in explosive strength were measured by the Counter Movement Jump Free Arms test and Two Step Run Up Jump test; agility was measured using the “T” Drill test and Hexagonal Obstacle test. The players participated in three measurements. The 1st (pretesting) was performed on the first day of pre-season, the 2nd (post-testing) was done two days after completing the PT program and the 3rd (post-testing) six weeks after completing the PT program. Friedman's ANOVA for repeated measurements was used to determine the significance of differences between the measurement sessions ($p < .05$). A significant effect of the training program was observed only for the Hexagonal Obstacle test ($p = .01$). A post hoc analysis revealed a significant increase in test performance between the 1st and 3rd measurement ($p < .01$) and between the 2nd and 3rd measurement ($p < .01$). The results of the study of elite basketball players did not positively support the assumption that plyometric exercises can be an effective tool for the improvement of explosive strength and agility. However, in some players the improvements corresponded to average improvements after training programs presented in literature (Lehnert, Hůlka, Malý, Fohler, & Zahálka, 2013).

In study of Makaruk & Sacewicz (2010), The study aims to determine the effect of plyometric exercises performed with minimum ground contact time on the maximal power output of the legs and jumping ability. This study sample comprised 44 non-training students of physical education. Following randomization, the experimental group performed plyometric exercises for six weeks, whereas the control group participated only in lectures. The subjects performed counter movement jumps (CMJ), depth jumps (DJ) and a five-hop test. After the completion of plyometric training, an increase in the relative maximal power output (p _ 0.001) in CMJ and DJ was observed, whereas the center of mass elevation and the five-hop test distance length did not change significantly ($p > 0.05$). Additionally, the rebound time in DJ was significantly shorter and the range of counter movement in the knee decreased (p __0.01). Depending on the aim of program, plyometric training should determine the ways of performing exercises. Methodological guidelines in plyometric training aimed at increasing the maximal power output may be different from indications concerning jumping ability (Makaruk & Sacewicz, 2010).

Chapter 3

Methodology

This chapter includes the chronological succession of material and method utilized in this study. So this chapter details Population and sampling; Research design of the study; Materials or Measures; Procedure; and Statistical process

The experimental methodology was used since it is convenient to the essence of the study. The One group Pre-test, Post-test design was adopted. Certain pilot studies have been conducted figure 5. Every study had aims different from other one. The pilot studies were of the adopted exercises in the study, conducting a training session, and the physical and skillful tests. (See table 5).

1		**2**		**3**		**4**		**5**		**6**
Pilot study	→	Pilot study	→	Pilot study	→	Pre-test	→	Executing Plyometric program	→	Post-test
↓		↓		↓		↓				↓
Adopting exercises		Conducting a training session		Checking physical and skillful tests		Physical and skillful tests				Physical and skillful tests

Figure 5. pilot and main studies

3.1 Population and sampling

Population

The society of this research study was determined intentionally from junior (under 16 years old) team handballers of Sumil youth center in Dohuk state at the athletic season of 2015-2016. The society was 20 handballers.

Sampling

After excluding goalkeepers and participants of the pilot studies, the sample was 14 handballers representing 70% of its society. Table 5 demonstrates numbers and percentages of the study's society and its sample in addition to the excluded participants of goalkeepers and participants of the pilot studies.

Table.5 Information of numbers and percentages of the study's society and its sample in addition to the excluded participants of goalkeepers and participants of the pilot studies.

	Number	%
Study's society	20	100 %
Study's sample	14	70 %
Sample of pilot studies	4	20 %
Goalkeepers	2	10 %

3.2 Materials or Measures (Data Collecting Tools)

Analysis of content, interview, questionnaire, test, and measurements were utilized as scientific tools to collect data.

1. Determination of the skillful and physical test

- **Determination of the physical test**

Having analyzing the content of literature to select certain tests, a questionnaire was offered on experts in the field of sport evaluation and measurement and team handball (see appendix A) to determine the most tests measuring the components of the explosive legs power, explosive arms power, legs power, and arms power (see appendix B). Having 77 % or more as a percentage agreement, the tests chosen to measure the physical components in question were of the vertical jump test, maximum single-leg hoping in 10 seconds test, 10 seconds push up test, and 900 gm. shoulder shot put. Table 6 details the agreement percentage of experts on the physical tests which measure a specific physical component.

Table.6 Ascending agreement percentages of experts to determine the physical tests.

Physical test	Physical component to be measured	Number of experts	Number of agreement	Percentage of agreements
vertical jump	explosive legs power	9	9	100 %
900 gm. shoulder shot put	explosive arms power	9	7	77 %
maximum single-leg hoping in 10 seconds	legs power	9	8	88 %
10 seconds push up test	arms power	9	7	77 %

- **Determination of the skillful test of the high jump shot**

Having analyzing the content of literature to select certain tests, a questionnaire was offered on experts in the field of sport evaluation and measurement and team handball (see appendix C) to determine the most proper test measuring the skill of high jump shot (see appendix D). Having 85 % as a percentage agreement, the test chosen was the high jump shot on 60×60cm. target.

2. Homogeneity of sample

- **Homogeneity of sample in chronological age, height, and weight**

The Homogeneity of sample in chronological age, height, and weight was processed by using coefficients of skewness and kurtosis. Table 7 details the arithmetic means, standard deviations, skewness's coefficient, and kurtosis coefficient of these variables.

Table.7 Descriptive statistics of chronological age, height, and weight for the basic participants of the sample.

Variable	$\bar{x}$	±SD
Chronological age (years)	15.23	0.55
Height (cm)	175.64	4.53
Weight (kg)	63,79	3.79

n=14, $\bar{x}$ = arithmetic mean, SD = standard deviation.

Table 7 demonstrate s that all values of the skewness's coefficient for the variables of chronological age, height, and weight approach to zero and he kurtosis's coefficient are between ±3 which indicate the normality and homogeneity of values of the study participants.

- **Homogeneity of the sample in skillful and physical components**

Homogeneity of the sample in variables of the shot, arms power, legs power, explosive arms power, and explosive legs power was processed by using coefficients of skewness and kurtosis. Table 8 details the arithmetic means, standard deviations, skewness's coefficient, and kurtosis coefficient of these variables.

Table.8 Descriptive statistics of skillful and physical components for the basic participants of the sample at pre test.

Variable	$\bar{x}$	±SD
shot	3,00	1,11
Vertical jump	46.21	4.19
Push up	9.29	1.49
Putting	17.34	3.02
right leg hoping	42,64	2,88
left leg hoping	41.84	4.69

n=14, $\bar{x}$ = arithmetic mean, SD = standard deviation.

Table 8 demonstrates that all values of the skewness's coefficient for the variables of the shot, vertical jump, push up, putting, right leg hopping, and left leg hopping approach to zero and he kurtosis's coefficient are between ±3 which indicate the normality and homogeneity of values of the study participants at pre test.

3. Explanatory and response variables

Explanatory variables are the variables which seek to predict or 'explain' the response variable. Also commonly known as the independent variables, although this is not to be recommended since they are rarely independent of one another (Everitt & Skrondal, 2010, p. 157). The explanatory variable in this research study is plyometric exercise.

Response/ Dependant variable is The variable of primary importance in investigations since the major objective is usually to study the effects of treatment and/or other explanatory variables on this variable and to provide suitable models for the relationship between it and the explanatory variables (Everitt & Skrondal, 2010, p. 369). The response physical variables of this research study are explosive legs power, explosive arms power, legs power, and arms power. The response skillful variables of this research study is the high jump shot.

4. Experimental design

Since the society of this study is very limited so that the sample (after exclusion subjects could not complete the treatment) is very near to its society, the One group Pre-test, Post-test design was adopted. Figure 5 illustrates the design.

Pre-test	Treatment	Post-test
O	X	O

Figure.6 Illustrates the adopted experimental design, One group Pre-test, Post-test

5. Internal and external validity

- **Internal validity**

The Internal validity of the experimental design was examined by controlling the following variables which affect the dependent variable:

1. Measurement tools used in study. This variable was controlled by uniform tools.
2. Experiment's circumstances and related factors. Certain factors such as mature, growth, and time wasting were controlled by obliging participant to attend all training sessions.

- **External validity**

To ensure the external validity of the experimental design, the experiment should has no errors or obstacles in order to generalize the findings of the study on similar samples. So, the homogeneity was achieved and the work team was selected from expertise in the field of coaching and teaching. In addition, the specified duration and place to conduct the experiment were concerned.

6. Tests and measurement utilized

- **Anthropometric measurements of standing height and body mass weight.**

Equipment required: stadiometer and Scale, which should be calibrated for accuracy.

Procedure**:**

Standing height. Shoes should be off, feet together, and arms by the sides when the participant is facing directly ahead. The measurement is the maximum and nearest 0.5 cm distance from the floor to the highest point on the head. Heels, buttocks and upper back should also be in contact with the wall when the measurement is made.

Body mass weight. The participant stays in the previous position with minimal movement. The weight will digitally appear in the screen of the scale to the nearest 0.2 kg. Excess clothing should be removed.

- **Physical tests**

Vertical Jump Test.

This procedure describes the method used for directly measuring the vertical jump height jumped.

Purpose**:** to measure the leg explosive muscle power.

Equipment required: measuring tape or marked wall, chalk for marking wall.

Procedure: the athlete stands side on to a wall and reaches up with the hand closest to the wall. Keeping the feet flat on the ground, the point of the fingertips is marked or recorded. This is called the standing reach height. The athlete then stands away from the wall, and leaps vertically as high as possible using both arms and legs to assist in projecting the body upwards. The jumping technique cannot use a countermovement. Attempt to touch the wall at the highest point of the jump.

Scoring**:** The jump height is usually recorded as a distance score. The difference in distance between the standing reach height and the jump height is the score. The better of two attempts is recorded (Hasanin & Abdulmunem, 1997). Figure 6 demonstrates the test.

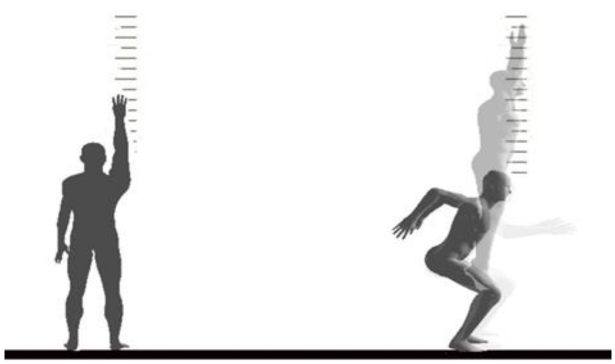

Figure.7 Illustrates the test of Vertical Jump Test.

Maximum single-leg hoping in 10 seconds Test

This is a test of leg power in which you have to perform consecutive single leg hoping in 10 seconds.

Purpose**:** to measure muscle power of the legs.

Equipment required: tape measure to measure distance jumped in meters, whistle, stopwatch, and flat area. The starting take off line should be clearly marked.

Procedure**:** The aim of this test is to perform multiple consecutive single-leg hops as far as possible in duration of 10 seconds. Stretch out approximately 9 meters of tape measure to mark the hopping direction and to aid recording the jump distance. The participant starts by standing behind a line with feet shoulder width apart. When ready and after hearing the start whistle, he is to perform multiple consecutive broad hops non-stop, using a forward as well as a vertical hope style that allows him to gain maximum distance in duration of 10 seconds starting and ending with a whistle. He is able to use his arms assist the explosive movement and for balance but without touching the ground. The same procedure is repeated for the other leg. Every participant has one attempt for each leg.

Scoring**:** The measurement is taken from take-off line to the nearest point of contact on the landing of the final hope at final whistle in the end of the 10th second (back of the heels). Record the longest distance hoped (K. H. Hussin & Bastawisi, 1979). Figure 7 demonstrate the test.

Figure.8 Illustrates the test of the Maximum single-leg hoping in 10 seconds Test

10 seconds Push Up Test

Purpose: to measure the arms power

Possible equipment required**:** floor ground, stopwatch, and whistle.

Procedure**:** The aim of this test is to perform as many push-ups as possible in 10 seconds. A push up begins with the hands and toes touching the floor, the body and legs in a straight line, feet slightly apart, the arms at shoulder width apart, extended and at a right angles to the body. Keeping the back and knees straight, the participant after hearing the start whistle lowers the body until his upper arms are at least parallel to the ground, then returns back to the starting position with the arms extended. This action is repeated, and test continues until hearing the final whistle in the end of the 10th second.

Scoring**:** Record the number of correctly completed push-ups over 10 seconds (Albadri & Alsudani, 2011). Figure 8 demonstrates the test.

Figure.9 Illustrates the 10 seconds Push Up Test

Test of 900 gm. Shoulder shot put

Purpose: to measure the explosive arms power.

Equipment required: 900 gm. iron shot, measurement tape, and small material signs numbered from 1 to 3. The shot should be noticed to be as small as hockey or soft ball.

The test should be applied in a flat area and free space. The throw is made from two parallel approach lines with 1.8 meters between. The shot must fall within a sector of parallel lines with 1.4 meters in between on the front of and cross the approach lines

Procedure: The participant commences the throw from a stationary position inside the approach lines and the shot must be put from the shoulder with one hand only and be kept in close proximity to the throwing sector.

When ready and after hearing a start signal, the participant throws the shot from the allowed 1.8 meters area to the throwing sector. Every participant has three successive trails. All participants should stay away from the throwing enclosure till everyone is called to perform his trails.

The test is administrated by one recorder and three judges. The recorder calls participants, monitoring the performance especially at approach area, and wright down the results. The judges measure distances and return the shots to the approach area after each three trails.

Scoring: the score of a participant is the best distance in which the shot travels and measured from start line to the nearest 1.4 meters in throwing sector. It should be noticed that the measurement tape be vertical on the start line (Allawi & Radwan, 2001). Figure 9 illustrates the test.

Figure.10 Illustrates the test of 900 gm. Shoulder shot put

Accuracy of high jump shot

Purpose: to measure the ability of a handballer to shoot the handball at goal using high jump shot with accuracy.

Equipment required: 8 team handballs, 4 squares of 60×60 cm, measuring tape, and adhesive tape.

Procedure: A shooting zone is marked on the 7 meters away from the goal halfway line. A 60×60 cm square is fixed at each angle of the goal. Catching a hanhball out of the shooting zone, the participant after hearing the start signal runs-up to approach the 7 meters line and perform a high jump shot at a specific square.

Comments: The shooting should be from behind the 7 meters line and not to touch it. The shot should be performed by jumping high. Any foul cancels the shot.

Scoring: a score is awarded when a ball go inside or hit any side of the specific square in the goal. The awarded are summed and listed down for each player (Ismail & Hasanin, 2002). Figure 10 illustrates the test.

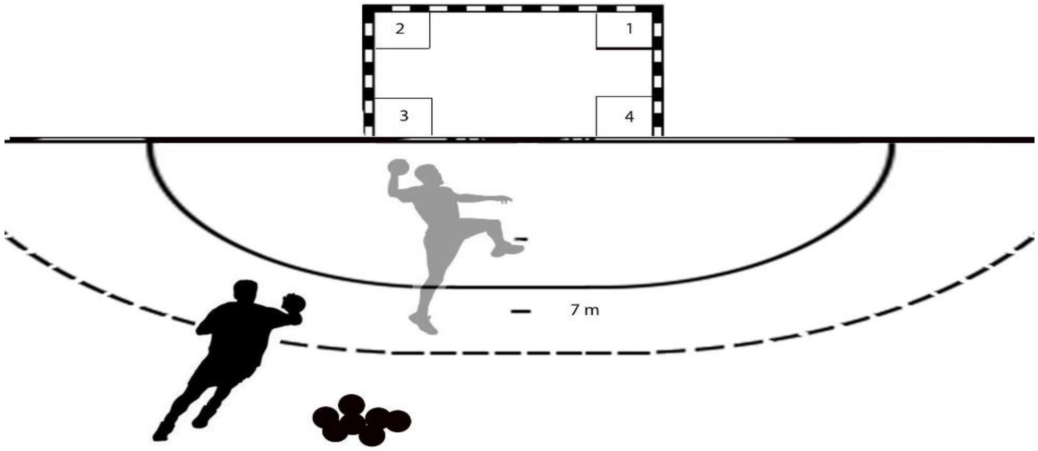

Figure.11 Illustrates the test of Accuracy of high jump shot

3 Equipment and tools utilized

1 team handball goal, 16 team handballs, 2 medicine balls, 2 stop watches, 1 stadiometer, 1 weight scale,2 chalk sticks, 1 bag of line marking powder, 2 adhesive tapes, 1 vertec, 4 benches, 5 boxes, 2 chairs, 1 ladder, and 1 shot of 900 gm.

3.3 Procedure

1. Designing exercise used in study

A questionnaire including plyometric exercise was designed by the student (see appendix E) then offered on certain experts in the field of coaching and team handball (see appendix G). The exercise were 8 with two exercises for each physical component in question. The physical components which selected previously by experts and properly designed to serve the study aims were distributed on these exercises.

2. Designing the training program

A questionnaire including the training program was designed (see appendix F) then offered on certain experts in the field of coaching and team handball (see appendix G) to check and change the training volume of the exercises repetitions designed by the student.

3. Pilot studies

Certain pilot studies have been conducted with assistance of a work team (see appendix H). Every study had aims different from other one. The pilot studies were as follows:

- **Pilot study of the adopted exercises in study**

This study had conducted in 12/07/2016 on four participants of the study society with assistant of the work team. The aims of this study were:

1. To control the time of the suggested exercises which will be used in the training program.
2. To acquaint with the interval relives between repetitions and sets of the suggested exercises which will be used in the training program.
3. To acquaint with the way by which the suggested exercises should be applied and how much they are proper for the study sample.
4. To acquaint with the limitations and difficulties may encounter the performing the exercises.
5. To determine the duties of each member of the work team.
6. To examine the efficiency of the work team and how perfect it is.

- **Pilot study for conducting a training session.**

This study had conducted in 13/07/2016 on also four participants of the study society with assistant of the work team. The aims of this study were:

1. To check executing the training session in its specific time.
2. To check executing the exercises in their specific part within the training session.
3. To check executing the number of repetitions and sets, in addition to the relief intervals between the sets according to the training program.
4. To check executing the suggested exercises of the adopted program in their specific time.
5. To examine the efficiency of the work team and how perfect it is to perform its duties throughout executing the training program.

- **Pilot study of the physical and skillful tests**

This study had conducted in 14/07/2016 on also four participants of the study society with assistant of the work team. The aims of this study were:

1. To examine the efficiency of the work team and how perfect it is to perform scoring throughout executing the tests.
2. To examine the efficiency of the equipment and tools used in all study tests.
3. To examine how the tests are proper to the sample and its response and interaction with tests.
4. To determine the scientific succession of the test in relation to their easiness and difficulty in addition to ensure that tests do will not affect each other.
5. To acquainted with the duration of every exercise, then to determine the required time to execute the tests.
6. To acquaint with the limitations and difficulties may encounter the performing the tests.

4. Pre tests

The physical and skillful pre tests had been conducted from 19/07 to 21/07/2016 and as follows:

- The 1st day of the 19/07/2016. The tests of explosive legs power and explosive arms power were conducted.
- The 2nd day of the 20/07/2016. The tests of legs power and arms power were conducted.
- The 3ed day of the 21/07/2016. The test of high jump shot was conducted.

To have a recovery, there was an appropriate relief between tests.

5. Executing the training program

The training program had been conducted from 23/07 to 15/09/2016 and the following points were concerned:

1. To commence a training session with warm up to prepare all body muscles then followed with specific warm up of active muscles of a specific exercise.
2. To end a training session with cool down and relaxation to all body muscles.
3. The training program included 8 weeks, micro cycles which were executed with two mezzo cycles. Every mezzo cycle has 4 micro cycles. The wave of workload of a mezzo cycle is (3:1).
4. Every micro cycle has 4 training sessions, that is, every group executed 32 training sessions throughout the whole program. The session were performed days of Saturday, Monday, Wednesday, and Thursday within the micro cycles. Other days of the week are as relief for the sample.
5. Four exercises were performed each training session so that the first exercise is for the legs explosive power, the second exercise is for the arms explosive power, the third exercise is for the legs power, and the fourth exercise is for the arms power.
6. The exercises of the legs and arms explosive power were performed with 100% intensity whereas the exercises of the legs and arms power were performed with 80% intensity.
7. The relief time among repetitions and among sets was determined in the pilot study so that the relief time among the repetitions of explosive power and power repetitions were 30 and 40 seconds respectively. Whereas the relief time among the sets of explosive power and power repetitions were 3 and 4 minutes respectively.
8. The wave of workload of every mezzo cycle was controlled by adjusting the workload volume, repetitions and sets. In addition, in the second and third weeks of every mezzo cycle the adaptation and stabilization principles were applied by fixing the volume.

6. Post tests

Having the training program finished, the post tests were applied on the sample from 17/09 to 19/09/201 with the same sequence of the pre tests.

7. Statistical process.

To process data statistically according to hypotheses where the null one (H_0) was adopted for all, the statistical package SPSS was utilized and the arithmetic mean, standard deviation, coefficient of variance, paired t test, percentage change $((pot\ test - pret\ est)/(pre\ test) \times 100)$ and percentage were used (Shorooq Mahdi Alkhylani, 2002).

CHAPTER 4
RESULTS

Presentation and discussion

In table.9 show the result of calculated t statistic and percentage change of pre-test and post-test in high jump shot for team handballers in question.

Table.9 Calculated t statistic and percentage change of pre-test and post-test in high jump shot for team handballers in question.

Variable	Pre-test		Post-test		t	p	PC%
	$\bar{x}$	SD	$\bar{x}$	±SD			
HJS	3,00	1,11	4,86	1,10	4,94	0.01*	88.6

n=14, HJS= High Jump Shot, $\bar{x}$= arithmetic mean, SD= Standard deviation, t= student's t statistic, P=portability, PC= percentage change,*p < 0.01

Table 9 demonstrates that there are significant differences between the pre-test and post-test in high jump shot since the calculated t, 4.94 is significant at probability level of p≤0.001. So, the null hypothesis (H_0) was rejected and the alternative one (H_1) was adopted statistically. The percentage change is 88.6% and it is for the sake of the post-test.

In table.10 show the result of calculated t statistic and percentage change of pre-test and post-test in Vertical Jump for team handballers in question.

Table.10 Calculated t statistic and percentage change of pre-test and post-test in Vertical Jump for team handballers in question.

Variable	Pre-test		Post-test		t	P	PC%
	$\bar{x}$	±SD	$\bar{x}$	±SD			
VJ	46,21	4,19	52,71	4,36	12.22	0.01*	14.25

n=14, VJ= Vertical Jump, $\bar{x}$= arithmetic mean, SD= Standard deviation, t= student's t statistic, P=portability, PC= percentage change, *p < 0.01

Table 10 demonstrates that there are significant differences between the pre-test and post-test in vertical jump since the calculated t, 12.22 is significant at probability level of $p \leq 0.001$. So, the null hypothesis (H_0) was rejected and the alternative one (H_1) was adopted statistically. The percentage change is 14.25 % and it is for the sake of the post-test.

In table.11 show the result of calculated t statistic and percentage change of pre-test and post-test in Push up for team handballers in question.

Table.11 Calculated t statistic and percentage change of pre-test and post-test in Push up for team handballers in question.

Variable	Pre-test		Post-test		t	P	PC%
	$\bar{x}$	±SD	$\bar{x}$	±SD			
PU	9,29	1,49	11,64	1,22	5.69	0.01*	27.93

n=14, PU= *Push up*, $\bar{x}$= arithmetic mean, SD= Standard deviation, t= student's t statistic, P=portability, PC= percentage change, $^{*}p < 0.01$

Table 11 Demonstrates that there are significant differences between the pre-test and post-test in push up since the calculated t, 5.69 is significant at probability level of $p \leq 0.001$. So, the null hypothesis (H_0) was rejected and the alternative one (H_1) was adopted statistically. The percentage change is 21.02 % and it is for the sake of the post-test.

In table.12 show the result of calculated t statistic and percentage change of pre-test and post-test in 900 gm. Shoulder shot put for team handballers in question

Table.12 Calculated t statistic and percentage change of pre-test and post-test in 900 gm. Shoulder shot put for team handballers in question.

Variable	Pre-test		Post-test		t	P	PC%
	$\bar{x}$	±SD	$\bar{x}$	±SD			
SSP	17,34	3,04	20,36	2,42	7.42	0.01*	18.75

n=14, SSP= Shoulder Shot Put, $\bar{x}$ = arithmetic mean, SD= Standard deviation, t= student's t statistic, P=portability, PC= percentage change, $^{*}p<0.01$

Table 12 demonstrates that there are significant differences between the pre-test and post-test 900 gm. Shoulder shot put since the calculated t, 7.42 is significant at probability level of ≤0.001. So, the null hypothesis (H_0) was rejected and the alternative one (H_1) was adopted statistically. The percentage change is 11.36 % and it is for the sake of the post-test.

In table.13 show the result of calculated t statistic and percentage change of pre-test and post-test in right-leg hoping for team handballers in question.

Table.13 Calculated t statistic and percentage change of pre-test and post-test in right-leg hoping for team handballers in question.

Variable	Pre-test		Post-test		t	p	PC%
	$\bar{x}$	±SD	$\bar{x}$	±SD			
RLH	42,64	2,88	48,68	3,77	6.11	0.01*	14.43

n=14, RLH= Right Leg Hoping, $\bar{x}$= arithmetic mean, SD= Standard deviation, t= student's t statistic, P=portability, PC= percentage change. *p<0.01

Table 13 demonstrates that there are significant differences between the pre-test and post-test in right-leg hoping since the calculated t, 6.11 is significant at probability level of p≤0.001. So, the null hypothesis (H_0) was rejected and the alternative one (H_1) was adopted statistically. The percentage change is 9.09 % and it is for the sake of the post-test.

In table.14 show the result of calculated t statistic and percentage change of pre-test and post-test in left-leg hoping for team handballers in question.

Table.14 Calculated t statistic and percentage change of pre-test and post-test in left-leg hoping for team handballers in question.

Variable	Pre-test		Post-test		t	P	PC%
	$\bar{x}$	±SD	$\bar{x}$	±SD			
LLH	41,84	4,69	46,31	4,79	5.22	0.01*	11.08

n=14, LLH= Left Leg Hoping, $\bar{x}$= arithmetic mean, SD= Standard deviation, t= student's t statistic, P=portability, PC= percentage change, $^{*}p<0.01$

Table 14 demonstrates that there are significant differences between the pre-test and post-test in left-leg hoping since the calculated t, 5.22 is significant at probability level of $p \leq 0.001$. So, the null hypothesis (H_0) was rejected and the alternative one (H_1) was adopted statistically. The percentage change is 8.20 % and it is for the sake of the post-test.

According to significant differences between the pre and post tests for values of all variables in this study and as illustrated in the findings above, all null hypothesis in this study were rejected and their alternative ones accepted.

CHAPTER 5

DISCUSSION

The propose of this research study was being acquainted with the effects of plyometric exercise on explosive power, power, and high jump shot of junior team handballers. Explanatory variable is plyometric exercise. The response physical variables are explosive legs power, explosive arms power, legs power, and arms power. The response skillful variable is the high jump shot.

Having analyzed the results of the skill of the high jump shot, there was a significant difference between pre and post tests and for the sake of post-test. This could be explained by the effectiveness of the exercises used in the plyometric program that led to the development of explosive strength and power for legs and arms. This explanation agrees with that of Radcliffe and Farentinos 1985 that plyometric exercises effect specifically on development of explosive strength and power (Radcliffe & Farentions, 1985).

The Plyometric exercise program had played a major role in improving the level of handballers in the high jump shot skill via the development of the explosive strength for legs and arms, that is, a certain skilful component could be developed by transfer the effects of certain physical components. This result agrees with those of Muhsen 1996, Amish 1999, and Karim 2002 who have reached the efficiency of plyometric exercise in developing the explosive strength and thus developing the skills they dealt in their studies.(Amish, 1999; Karim, 2002; Muhsen, 1996).

In addition, the effective periodization of the current program to reach the performance aims was obvious and could be assessed in this study. As a result, the successful high jump shot which demands a strength and speed jump against obstacle of opponents defender body had improved via gaining a handballer a significant explosive strength. In other hand, while expanding the knee as fast and strong as possible, the power transfers from muscles of leg to trunk to achieve the required strength to throw the ball and the performance will be stronger as long as this transferred strength high. Also, the height of jump has a positive effect in increasing the flight time in air which enables the handballer to perform his shot properly. Accordigly, the plyometric exercise in this study had improved the strength of the leg muscles and thus it had improved of explosive strength.

The fact of a relation between the explosive strength and performance is emphasized by Abululla 1997 who states that “the better explosive strength the player has the higher his performance” (Abdulfatah, 1997) to perform The technique of shot skill perfectly, a handballer demands proper physical components because this skill demands high speed and high jump before shooting. The plyometric program in this study achieved these demands and these findings agree with those of Selva 2000 in that the specific plyometric exercise has an effect on improving the explosive strength for legs and arms and improving the skill performance (Sahak, 2000).

Selecting a training tool depending upon precise diagnosis and description of skill performance determines the role of the muscular strength could be played as a basic physical component of this performance. The training style of specific strength related to this performance depends upon the dynamic features of this skill performance as a key base to select the training tool and to build the exercise either as a frame or as a quantity of resistance, performance rhythm, repetitions, or any other techniques needed for specific training (H. T. Hussin, 1994).

The proper periodization of plyometric exercise increases the explosive strength of the leg needed by skilful performance, especially if these exercises simulate and fellow the essence of the skill performance so that the speed integrates with the strength to achieve a high performance" (Gambetta, 1989).

Discussion of physical components

Having analyzed the results of physical tests for variables of the explosive strength and power of the legs and arms, there was a significant difference between pre and post tests for the sake of the post-test. So, the null hypotheses was rejected and the alternative one accepted. This result may be resulted from the effectiveness of the exercises used in the plyometric exercises that led to the development of explosive power and power for arms and legs. The researcher thinks that these physical components have a great importance to the handballers and this be in agreement with Pollock & Wilmore 1980 who stated that "the explosive strength comes in the first place among the order of physical abilities in most sports activities" (Pollock & Wilmore, 1990). These results consistent with a study of Dick 1980 which indicated the effects of the plyometric training in increasing the explosive strength and the alternative correlation between the increase in strength of the legs and arms muscles to the results of the explosive strength. In addition, the researcher followed the scientific basis of adopting the principle of overload in which the repetitions increased, according to the volume to be proper for the sample of the study.

Also, the training sessions which included the use of physical exercises of strength, has led to improve the level of the muscle power of the arms, which meets the need of handballer for these components perform requirements and duties of the modern game. This study proved the efficiency of training method used to train the muscle power of the Handballer according to his demands to perform motor task of the game's skills. The plyometric exercises had also increased the overall muscle power and enhanced it more effectively because power is an aspect of the basic strength which the latter includes the maximum strength, explosive strength, and power. Power is a mixed component of the speed and strength, but to varying degrees depending on the nature of the event or skill. So, an athlete requires the high ability of the nervous and muscular systems in integrating the strength and speed in a single component with a specific coordination. sport activities having like this demand of integrating strength and speed in a specific period include team handball and this is consistent with Chu 1992 who emphasized the plyometric training is "a training style of can be the sports in which an athlete could access to the fast maximum strength in the shortest possible time" (Chu, 1998).

It seems that the positive correlation between the strength, power and the shot in this study resulted from the great rush and high dynamic which dominated the plyometric training. This helped the participants to utilize the motor transfer of the legs explosive strength in increasing the strength and accuracy of shooting. In this context, Daboor 1997 emphasized that "athletes should utilize motor compound actions with various aspects so that each has a specific role serving the overall performance in a manner be convenient for the overall objective of the performance " (Daboor, 1997).

The success of plyometric exercises, which included exercises to develop explosive strength and power of the legs and arms could be resulted from the principle of specificity in training. This specificity manifested in training workloads within the range of the maximum or near-maximum intensities and the relationship between exercise intensity, performance time, and reliefs according to the tests of the explosive strength, jumping, medicine ball throwing, power alternative jumps, bending and expanding with fast rhythm to integrate the components of strength and speed. The exercises of the deep jump, box, and countermovement had an effective role on the explosive strength and power of the legs and arms. Levchenko, and Maven had indicated the positive effects of the plyometric exercise which includes various jumping exercises depending basically upon falling from the high place with single or two legs on the floor then followed with high strength and speed above or forward. Such as these exercises depends upon the shortening–lengthening cycle of the skeletal muscle, which generates a power, “the ability to generate maximum strength within shortest time (Johnson & Nelson, 1979). Also, the increasing in the explosive strength had contributed in generating an additional strength of the active muscles and accelerating the movement of shooting arm. The enhancement of the bending and the expanding chain of the muscle throughout eccentric lengthening which is energized and utilized in the next concentric contraction leads to increase the strength and flexibility of the active muscles and thereafter the strength and speed integration and the coordination increasing led to enhancement the speed of the motor performance. This agreed with the study of Radcliffe 2006 which resulted in a positive effect of using plyometric exercises of medicine balls, like those used in this study in improving the explosive strength (Radcliffe, 2006).

each of Levchenko, a, and Maven had pointed out the positive effect of exercise plyometric which includes various jumping exercises depending basically upon the drop with single-leg and legs from a high place to the ground, followed by a strong and fast vertical jump upward or forward. Such as these exercises depend upon stretching-shortening cycle (SSC) that is, stretching a muscle and then shortening it to produce high explosive power. The explosive power is "the ability to produce a maximum force in the shortest possible time" (Johnson & Nelson, 1979). The increase of explosive power of the arm muscles contributed also to generate extra power of the active muscles and accelerate the shooting arm. The improvement of SSC in muscle enhances restoration of the elastic energy during eccentric contraction which is used in the next and immediate concentric contraction leads to increase the strength of active muscles and improve flexibility so that the strength and speed of movements manifest simultaneously and the coordination increase. This will enhance the motor performance and agree with a study of Radcliffe 2006 which resulted in positive effects for developing explosive power by using medical balls exercises, which were utilized with plyometric in this study (Radcliffe, 2006).

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- HJS showed significant change in pre-post test values as means of 3±1.11 and 4.86±1.10, t=4.94 with a p<0.01, change % 88.6 respectively.
- VJ showed significant change in pre-post test values as means of 46.21±4.19 and 52.71±4.36, t=12.22 with a p<0.01, change % 14.25 respectively.
- PU showed significant change in pre-post test values as means of 9.29±1.49 and 11.64±1.22, t=5.69 with a p<0.01, change % 27.93 respectively.
- SSP showed significant change in pre-post test values as means of 17.34±3.04 and 20.36±2.42, t=7.42 with a p<0.01, change % 18.75 respectively.
- RLH showed significant change in pre-post test values as means of 42.64±2.88 and 48.68±3.77, t=6.11 with a p<0.01, change % 14.43 respectively.
- LLH showed significant change in pre-post test values as means of 41.84±4.69 and 46.31±4.79, t=5.22 with a p<0.01, change % 11.08 respectively

6.2 Recommendations

- This study of plyometric effects should be replicated and reported in variables of explosive strength of arms and legs in addition to the high jump shot with collecting additional qualitative data from other situations, participants, and level of experiences. The methodology of this study could be utilized in future research.

- To have more insights, this study of plyometric effects should be replicated and reported in other situations with collecting additional qualitative data from other sports, participants, and level of experiences.
- It would be valuable to adopt or consider the effects of Plyometric training to improve the explosive strength of arms and legs.
- It would be valuable to adopt or consider the effects of Plyometric training to improve the shot skill especially the high jump shot.
- The findings of this study should be utilized and generalize in the youth centers,
- Periodical tests for revealing the actual level of team handballers should be conducted.

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APPENDICES

Appendix A. List of experts

Tests of explosive power and power for arms and leg

F	Name	discipline	Job title	Institute
1.	Dr., Eyad Mohammed Abdullah	Science of coaching	Professor	College of physical education and sport sciences. University of Mosul
2.	Dr., Durgham Jasem Mohammed	Measurement and evaluation	Professor	College of physical education and sport sciences. University of Mosul
3.	Dr., Mutaz Younis Dhanoon	Science of coaching	Professor	College of basic education. University of Mosul
4.	Sadi Omer Yousef	Team handball	Associated Professor	College of sport education, university of Dohuk
5.	Dr., Jalal kamal Mohammed	Measurement and evaluation	Associated Professor	College of sport education, university of Dohuk
6.	Dr., Yahya Mohamed Ali Mohammed	Team handball	Lecturer	College of basic education. University of Mosul
7.	Dr., Sabah Mati Fathullah	Team handball	Lecturer	College of basic education. University of Mosul
8.	Jamil Ahmed Hussain	Measurement and evaluation	Lecturer	College of sport education, university of Dohuk
9.	Dulovan Asad Nabi	Team handball	Assistant Lecturer	College of sport education, university of Dohuk

Appendix B. Expertise questionnaire

Tests of explosive power and power for arms and leg

Dear expert,

This research study examines Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power of under 16 years old Junior Team Handballers. The principle researcher for this study is Hariwan Abid Taher, a student under supervision of prof. Dr. CEVDET TINAZCL in the Institute of Health Sciences at Near East University. The results from this study will contribute to a better understanding Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power. This knowledge can provide insight into the development of appropriate training strategies to maximize the physical and skillful benefits for handball to improve tier performance

The researcher had been reviewed the literature to outline the appropriate tests of the explosive power and power for arms and leg. If you want to go ahead and help me, please respond to statements, sign your name on the line below, and write the rest information.

If you could please suggest any alternative test you think it is appropriate and it is not included in this list

Signature: …………………

Date: …………………

Name: …………………

Job title: …………………

Discipline: …………………

Institution: …………………

Please indicate your best respond by checking the mark (√) inside the cell that follows each test.

Tests of leg explosive power	Check mark
Standing Long Jump Test (Broad Jump)	( )
Standing vertical jump test	( )
Abalakov Jump test	( )
Tests of arm explosive power	**Check mark**
Overhead 2kg Medicine Ball Throw (by hands from standing and forwards)	( )
2kg Medicine Ball push	( )
80gm Medicine Ball Shoulder Throw	( )
900 gm. Shoulder shot put	( )
Tests of leg power	**Check mark**
20secnds free squat test	( )
30 meters single leg hope	( )
10seconds maximal single leg hope	( )
Tests of arm power	**Check mark**
Pull-Up / Chin Up Test	( )
Parallette Push-Up	( )
10second maximal bench press	( )
10 second push up	( )

Appendix C. Arabic version of the expertise questionnaire

Tests of explosive power and power for arms and leg

جامعة قبرص
كلية التربية الرياضية
الدراسات العليا

أنموذج استبيان لاخذ اراء السادة المتخصصين في مجالات القياس والتقويم والتدريب الرياضي و كرة اليد لتحديد انسب اختبار للقوة الانفجارية والقوة المميزة بالسرعة للذراعين والرجلين

الأستاذ الفاضل .... المحترم

السلام عليكم ... يروم الباحث إجراء بحثه الموسوم " **تأثير تمرينات البليومتريـــك فـــي مهارة التصويب من القفزعاليا وصفتي القوة الانفجارية والقوة المميزة بالسرعة للاعبي كـــرة اليد**" على عينة من فئة الشباب ويهدف البحث الكشف عن اثر تمرينات البليومتريك على القوة الانفجارية والقوة المميزة بالسرعة للذراعين والرجلين وعلى التصويب من القفز ، ونظرا لما تتمتعون به من خبرة علمية وعملية في مجالات القياس والتقويم والتدريب الرياضي و كرة اليد يرجى بيان رأيكم لاختيار انسب اختبار للقوة الانفجارية للرجلين والذراعين وانسب اختبار للقوة المميزة بالسرعة للرجلين والذراعين من مجموع الاختبارات المرفقة في الاستمارة ، اذ تم تحديد هذه الاختبارات من خلال تحليل محتوى المصادر العلمية .

ملاحظة

- ترشيح اي اختبار بديل في حالة عدم صلاحية الاختبارات المذكورة .

شاكرين حسن تعاونكم

الاسم الكامل :
اللقب العلمي :
التخصص :
الكلية والجامعـــــة :
التأريـــــخ :
التوقيــــع :

طالب الماجستير
هاريوان عابد طاهر

الإشارة	اختبارات القوة الانفجارية للرجلين
( )	الوثب الطويل من الثبات
( )	القفز العمودي من الثبات
( )	اختبار ابالاكوف
الإشارة	اختبارات القوة الانفجارية للذراعين
( )	رمي الكرة الطبية وزن (2 كغم) باليدين من فوق الرأس من وضع الوقوف
( )	دفع الكرة الطبية وزن (2كغم)
( )	اختبار رمي الكرة الطبية بمستوى الكتف 800 غم
( )	رمي ثقل زنة (900) غم من مستوى الكتف
الإشارة	اختبارات القوة المميزة بالسرعة للرجلين
( )	اختبار ثني ومد الرجلين من مفصل الركبتيـــن لمدة (20) ثانية
( )	الحجـــــــل علـــى ســـاق واحــدة لمسافـــــة (30) متر
( )	الحجـــــــل لأقصى مسافة خلال (10) ثواني لكل رجل على حده
الإشارة	اختبارات القوة المميزة بالسرعة للذراعين
( )	سحب على العقلة
( )	من وضع الاستناد على المتوازي الواطئ ثني الذراعين ومدهما
( )	اختبار الضغط من الاستلقاء على المصطبة (Bench Press) لاداء اكبر المستوية عدد من التكرارات خلال (10) ثوان
( )	اختبار ثني الذراعين ومدهما من وضع الانبطاح لمدة (10) ثواني

Appendix D . List of experts

Tests of high jump shot

F	Name	discipline	Job title	Institute
1.	Dr., Durgham Jasem Mohammed	Measurement and evaluation	Professor	College of physical education and sport sciences. University of Mosul
2.	Sadi Omer Yousef	Team handball	Associated Professor	College of sport education. University of Dohuk
3.	Dr., Jalal kamal Mohammed	Measurement and evaluation	Associated Professor	College of sport education, university of Dohuk
4.	Dr., Yahya Mohamed Ali Mohammed	Team handball	Lecturer	College of basic education. University of Mosul
5.	Dr., Sabah Mati Fathullah	Team handball	Lecturer	College of basic education. University of Mosul
6.	Jamil Ahmed Hussain	Measurement and evaluation	Lecturer	College of sport education. university of Dohuk
7.	Dulovan Asad Nabi	Team handball	Assistant Lecturer	College of sport education. university of Dohuk

Appendix E. Expertise questionnaire

Tests of high Jump Shot

Dear expert,

This research study examines Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power of under 16 years old Junior Team Handballers. The principle researcher for this study is Hariwan Abid Taher, a student under supervision of prof. Dr. CEVDET TINAZCL in the Institute of Health Sciences at Near East University. The results from this study will contribute to a better understanding Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power. This knowledge can provide insight into the development of appropriate training strategies to maximize the physical and skillful benefits for handball to improve tier performance

The researcher had been reviewed the literature to outline the appropriate tests of the high Jump Shot. If you want to go ahead and help me, please respond to statements, sign your name on the line below, and write the rest information.

If you could please suggest any alternative test you think it is appropriate and it is not included in this list

Signature: …………………

Date: …………………

Name: …………………

Job title: …………………

Discipline: …………………

Institution: …………………

Please indicate your best respond by checking the mark (√) inside the cell that follows each test.

Tests of shot	Check mark
12 balls high jump shot	( )
10 balls high jump shot	( )
8 balls high jump shot on 60×60 cm target	( )
Speed of 5 balls dribbling and shooting	( )

Appendix F. Arabic version of the expertise questionnaire

Tests of high Jump Shot

جامعة قبرص
كلية التربية الرياضية
الدراسات العليا

أنموذج استبيان لاخذ اراء السادة المختصين في مجالي القياس والتقويم و كرة اليد لتحديد انسب اختبار للتصويب من القفزعاليا.

الأستاذ الفاضل .... المحترم

السلام عليكم ... يروم الباحث إجراء بحثه الموسوم " **تأثير تمرينات البليومتريك في مهارة التصويب من القفزعاليا وصفتي القوة الانفجارية والقوة المميزة بالسرعة للاعبي كرة اليد**" على عينة من فئة الشباب ويهدف البحث الكشف عن اثر تمرينات البليومتريك على التصويب من القفز وعلى القوة الانفجارية والقوة المميزة بالسرعة للذراعين والرجلين ، ونظرا لما تتمتعون به من خبرة علمية وعملية في مجالي القياس والتقويم و كرة اليد يرجى بيان رأيكم لاختيار انسب اختبار للتصويب من القفزعاليا من مجموع اختبارات التصويب المرفقة في الاستمارة ، اذ تم تحديد هذه الاختبارات من خلال تحليل محتوى المصادر العلمية .

ملاحظة

- ترشيح اي اختبار بديل في حالة عدم صلاحية الاختبارات المذكورة .

شاكرين حسن تعاونكم

الاسم الكامل :
اللقب العلمي :
التخصص :
الكلية والجامعة :
التأريخ :
التوقيع :

طالب الماجستير
هاريوان عابد طاهر

الإشارة	اختبارات التصويب
( )	اختبار التصويب عاليا 12 كرات
( )	اختبار التصويب من الوثب عاليا 10 كرات
( )	اختبار بالوثب العالي على هدف محدد 60*60 بالدرجة 8 كرات
( )	اختبار السرعة والتنطيط والتصويب 5 كرات

Appendix G. Expertise questionnaire

Suggested exercise of plyometric

Dear expert,

This research study examines Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power of under 16 years old Junior Team Handballers. The principle researcher for this study is Hariwan Abid Taher, a student under supervision of prof. Dr. CEVDET TINAZCL in the Institute of Health Sciences at Near East University. The results from this study will contribute to a better understanding Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power. This knowledge can provide insight into the development of appropriate training strategies to maximize the physical and skillful benefits for handball to improve tier performance

The researcher had been designed certain exercise of plyometric. If you want to go ahead and help me, please respond to statements, sign your name on the line below, and write the rest information.

If you could please suggest any alternative exercise you think it is appropriate and it is not included in this list

Signature: …………………

Date: …………………

Name: …………………

Job title: …………………

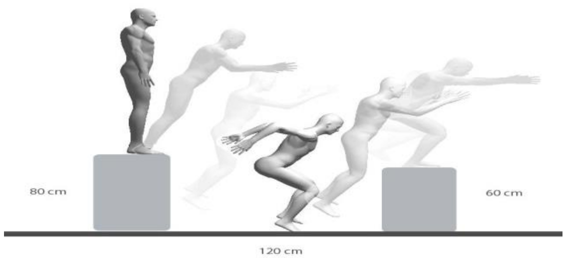
Discipline: …………………

Institution: …………………

Please indicate your best respond by checking the mark (√) in front of the cell that follows each exercise.

Exercise 1: Legs Depth Jump Check mark ( )

This exercise aims at improving the explosive power of legs. Duration of this exercise is 2 second during which the participant perform deep jump with two legs from over an 80cm high box then to counter jump to a 60cm high box120cm away from the first box. The next figure illustrates that.



Exercise 2: Single-leg Depth Jump Check mark ( )

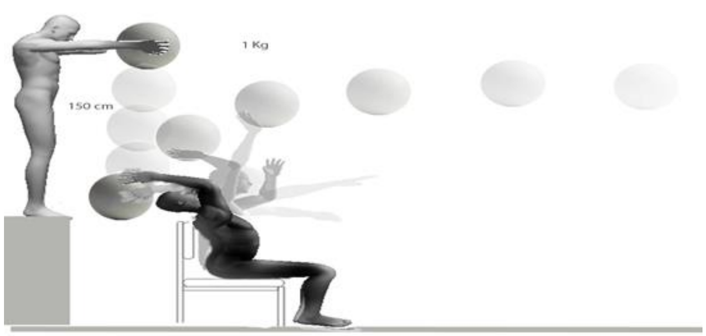
This exercise aims at improving the explosive power of the pivot leg. Duration of this exercise is 2 second during which the participant perform deep jump with single leg from over a 60cm high box then to counter jump to a 40cm high box100cm away from the first box. The next figure illustrates that.

Exercise 3: Arms Power Drop Check mark ( )

This exercise aims at improving the explosive power of the arms. Duration of this exercise is 2 second. The participant sets on a little backward inclined chair with fixing his trunk to chair by a bond. the participant receives by his hands a 2 kg medicine ball falling from 150 cm high then propel it immediately forward. The next figure illustrates that.

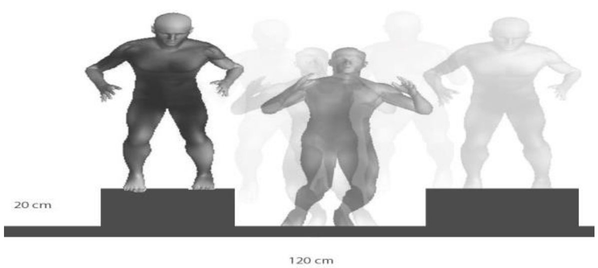
Exercise 4: Single-arm Power Drop Check mark ( )

This exercise aims at improving the explosive power of the master arm. Duration of this exercise is 2 second. The participant sets on a little backward inclined chair with fixing his trunk to chair by a bond, the participant receives by his hands a 1 kg medicine ball falling from 150cm high then propel it immediately forward by his master hand. The next figure illustrates that.



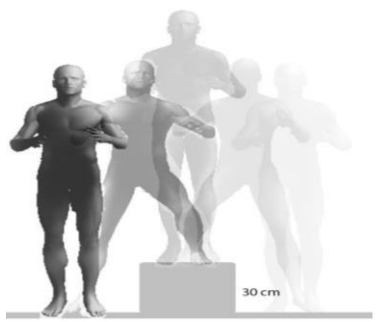
Exercise 5: Lateral Box Jumps Check mark ( )

This exercise aims at improving the explosive power of the legs. Duration of this exercise is 2 seconds. The participant Stands on the left of the first Plyo box, his feet hip-distance apart. He Lands down laterally on the floor. Essentially, he must land on the balls of his feet, his feet approximately hip-distance apart, with his knees and hips slightly bent to help absorb the impact before sinking down onto his heels. He should avoid allowing his knees to cave inward or outward - making sure they track in line with his toes without extending *past* his toes. From the last position, he explodes up and to the right as he swing his arms forward, aiming to jump on the center of the second box. Repeat in fast rhythm. The next figure illustrates that.



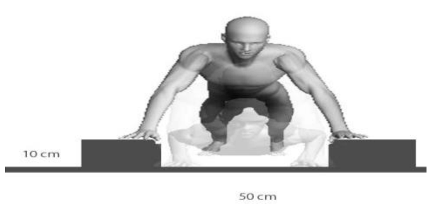
Exercise 6: Lateral Box Push Offs Check mark ( )

This exercise aims at improving the power of the legs. Duration of this exercise is 10 seconds. The participant stands to side of a 30 cm high box and places the left foot on top of box. He Pushes off the box using the left leg only and explodes vertically as high as possible. He drives the arms forward and up for maximum height. He Lands with right foot on the box and left foot on the ground to the other side of the box. .Repeat from this side in fast rhythm. The next figure illustrates that.



Exercise 7: drop Push-Ups Check mark ( )

This exercise aims at improving the power of the arms. Duration of this exercise is 10 seconds. The participant starts by getting into a push-up position on two boxes of 10 cm high and 50 cm apart. He drops his chest from the boxes close to the floor and then explosively pushes up so that his hands leave the ground and back again in the starting position on the two boxes. Repeat in fast rhythm. The next figure illustrates that.



Exercise 8: Plyometric Push-Ups with a clap Check mark ( )

This exercise aims at improving the power of the arms. Duration of this exercise is 10 seconds. The participant starts by getting into a push-up position. He Lowers his chest close to the ground and then explosively pushes up so that his hands leave the ground and claps his hands together. He lands his hands back in the starting position and repeats in fast rhythm. The next figure illustrates that.

Appendix H. Arabic version of the expertise questionnaire

Suggested exercise of plyometric

جامعة قبرص

كلية التربية الرياضية

الدراسات العليا

أنموذج استبيان لاخذ اراء السادة المتخصصين في مجالي التدريب الرياضي و كرة اليد حول التمارين التي تم تصميمها للبرنامج التدريبي

الأستاذ الفاضل .... المحترم

السلام عليكم.... يروم الباحث إجراء بحثه الموسوم " **تأثير تمرينات البليومتريك في مهارة التصويب من القفزعاليا وصفتي القوة الانفجارية والقوة المميزة بالسرعة للاعبي كرة اليد فئة الناشئين (تحت 16 سنة)**" على عينة من فئة الناشئين ويهدف البحث الكشف عن اثر تمرينات البليومتريك على التصويب من القفز وعلى القوة الانفجارية والقوة المميزة بالسرعة للذراعين والرجلين، ونظرا لما تتمتعون به من خبرة علمية وعملية في مجالي التدريب الرياضي و كرة اليد يرجى بيان رأيكم حول التمارين التي تم تصميمها للبرنامج التدريبي المرفقة في الاستمارة.

شاكرين حسن تعاونكم

الاسم الكامل :

اللقب العلمي :

التخصص :

الكلية والجامعة :

التأريخ :

التوقيع :

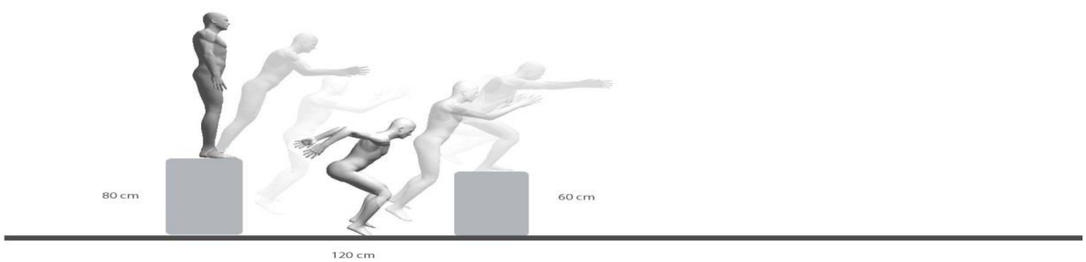
طالب الماجستير

هاريوان عابد طاهر

تمارين البلايومتريك

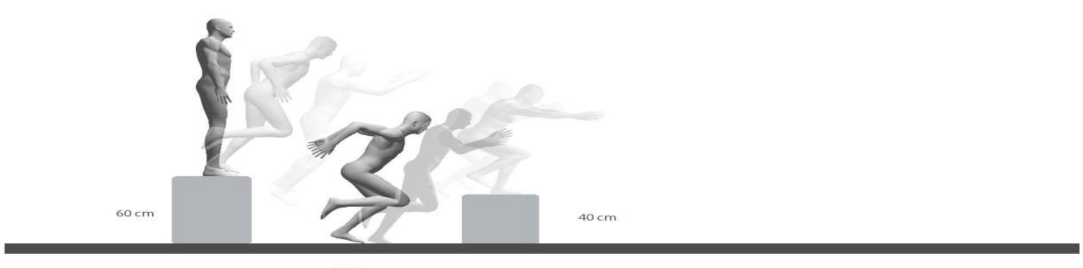
التمرين رقم 1 القفز العميق بالساقين علامة الاختيار ( )

الهدف من التمرين هو تطوير القوة الانفجارية للرجلين زمن التمرين هو (2) ثانية يقوم اللاعب بالقفز العميق بالرجلين معا من فوق صندوق ارتفاعه (80) سم على الارض ومن ثم يقفز على صندوق اخر ارتفاعه (60) سم ويبعد عن الصندوق الاول (120) سم وكما موضح بالشكل .



التمرين رقم 2 القفز العميق بساق واحدة علامة الاختيار ( )

الهدف من التمرين هو تطوير القوة الانفجارية لرجل الارتكاز زمن التمرين هو (2) ثانية يقوم اللاعب بالقفز العميق برجل واحدة من فوق صندوق ارتفاعه (60) سم على الارض ومن ثم يقفز على صندوق اخر ارتفاعه (40) سم ويبعد عن الصندوق الاول (100) سم وكما موضح بالشكل .



التمرين رقم 3 سقوط الكرة للذراعين علامة الاختيار ( )

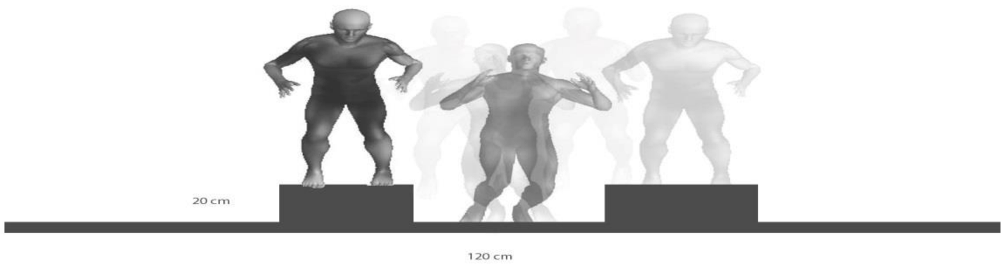
الهدف من التمرين هو تطوير القوة الانفجارية للذراعين زمن التمرين هو (2) ثانية يجلس اللاعب على كرسي مائل قليلا للخلف يكون جذعه مثبتا بالكرسي بشريط رابط، يقوم باستقبال كرة طبية زنة (2) كغم ساقطة من ارتفاع (150) سم بالذراعين وبعد الاستقبال مباشرة يرميها الى الامام بالذراعين وكما موضح بالشكل .

التمرين رقم 4 سقوط الكرة لذراع واحدة علامة الاختيار ( )

الهدف من التمرين هو تطوير القوة الانفجارية للذراع الرامية زمن التمرين هو (2) ثانية يجلس اللاعب على كرسي مائل قليلا للخلف يكون جذعه مثبتا بالكرسي بشريط رابط، يقوم باستقبال كرة طبية زنة (1) كغم ساقطة من ارتفاع (150) سم بالذراعين وبعد الاستقبال مباشرة يرميها الى الامام بذراع واحدة (الذراع الرامية) وكما موضح بالشكل .

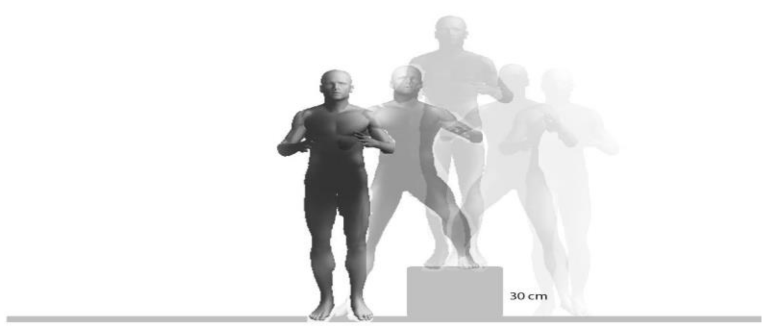
التمرين رقم 5 القفز العميق الجانبي بالساقين علامة الاختيار ( )

الهدف من التمرين هو تطوير القوة المميزة بالسرعة للرجلين زمن التمرين هو (10) ثواني يقوم اللاعب بالقفز الجانبي بالرجلين معا من فوق المصطبة الاولى الى الارض ومن ثم يصعد بالرجلين معا على المصطبة الثانية وثم يقفز الى الارض من فوق المصطبة الثانية ثم يصعد على المصطبة الاولى ارتفاع المصطبتين (20) سم والمسافة بينهما (100) سم وهكذا يستمر التمرين بايقاع سريع لمدة (10) ثواني وكما موضح بالشكل .



التمرين رقم 6 القفز العميق الجانبي بساق علامة الاختيار ( )

الهدف من التمرين هو تطوير القوة المميزة بالسرعة للرجلين زمن التمرين هو (10) ثواني يقوم اللاعب بالصعود برجل واحدة على صندوق رتفاعه (30) سم ومن ثم يصعد بالرجل الاخرى ثم ينزل بالرجل الاولى ثم الثانية ويكرر نفس التمرين من الجهة التي هبط بالرجلين فيها وهكذا يستمر التمرين بايقاع سريع لمدة (10) ثواني وكما موضح بالشكل .



التمرين رقم 7 شناو ساقط علامة الاختيار (   )

الهدف من التمرين هو تطوير القوة المميزة بالسرعة للذراعين زمن التمرين هو (10) ثواني يقوم اللاعب باداء تمرين الاستناد الامامي بين مصطبتين ارتفاعهما (10) سم والمسافة بينهما (50) سم بحيث تكون ذراعا اللاعب عند بدء التمرين فوق المصطبتين ويبدا التمرين بالهبود بالذراعين على الارض بين المصطبتين ومن ثم الصعود مرة اخرى بالذراعين على المصطبتين وهكذا يستمر التمرين بايقاع سريع لمدة (10) ثواني وكما موضح بالشكل.

التمرين رقم 8 شناو بليومترك مع صقفة اليدين علامة الاختيار ( )

الهدف من التمرين هو تطوير القوة المميزة بالسرعة للذراعين زمن التمرين هو (10) ثواني يقوم اللاعب باداء تمرين الاستناد الامامي بحيث عند ترك الذراعين للارض يقوم بضرب راحة اليدين ببعضهما مثل عملية التصفيق وهكذا يستمر التمرين بايقاع سريع لمدة (10) ثواني وكما موضح بالشكل.

Appendix I. Expertise questionnaire

Goodness of training program

Dear expert,

This research study examines Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power of under 16 years old Junior Team Handballers. The principle researcher for this study is Hariwan Abid Taher, a student under supervision of prof. Dr. CEVDET TINAZCL in the Institute of Health Sciences at Near East University. The results from this study will contribute to a better understanding Effects of Plyometric Exercise on the skill of high Jump Shot and components of explosive power and power. This knowledge can provide insight into the development of appropriate training strategies to maximize the physical and skillful benefits for handball to improve tier performance

The researcher had been designed a suggested training program of plyometric exercise.. If you want to go ahead and help me to determine the goodness of this program, please respond to statements, sign your name on the line below, and write the rest information.

If you could please suggest any alternative information you think it is appropriate and it is not included in this program

Signature: …………………

Date: …………………

Name: …………………

Job title: …………………

Discipline: …………………

Institution: …………………

Points will be concerned throughout executing the training program

1. To commence a training session with warm up to prepare all body muscles then followed with specific warm up of active muscles of a specific exercise.
2. To end a training session with cool down and relaxation to all body muscles.
3. The training program included 8 weeks, micro cycles which were executed with two mezzo cycles. Every mezzo cycle has 4 micro cycles. The wave of workload of a mezzo cycle is (3:1).
4. Every micro cycle has 4 training sessions, hat is every group executed 32 training sessions throughout the whole program. The session were performed days of Saturday, Monday, Wednesday, and Thursday within the micro cycles. Other days of the week are as relief for the sample.
5. Four exercises were performed each training session so that the first exercise is for the legs explosive power, the second exercise is for the arms explosive power, the third exercise is for the legs power, and the fourth exercise is for the arms power.
6. The exercises of the legs and arms explosive power were performed with 100% intensity whereas the exercises of the legs and arms power were performed with 80% intensity.
7. The relief time among repetitions and among sets was determined in the pilot study so that the relief time among the repetitions of explosive power and power repetitions were 30 and 40 seconds respectively. Whereas the relief time among the sets of explosive power and power repetitions were 3 and 4 minutes respectively.
8. The wave of workload of every mezzo cycle was controlled by adjusting the workload volume, repetitions and sets. In addition, in the second and third weeks of every mezzo cycle the adaptation and stabilization principles were applied by fixing the volume.

Training program of the experimental group/1st mezzo cycle/1st week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume Reps.	set	Relief Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	Aim to be improved by Ex.
1st	1	1	2	100	3	2	30	3	Neg	3	Legs explosive power
		3	2	100	3	2	30	3	Neg	4	Arms explosive power
		5	10	80	2	2	90	4	Neg	4	Legs power
		7	10	80	2	2	90	4	Neg		Arms power
	2	2	2	100	3	2	30	3	Neg	3	Legs explosive power
		4	2	100	3	2	30	3	Neg	4	Arms explosive power
		6	10	80	2	2	90	4	Neg	4	Legs power
		8	10	80	2	2	90	4	Neg		Arms power
	3	1	2	100	3	2	30	3	Neg	3	Legs explosive power
		3	2	100	3	2	30	3	Neg	4	Arms explosive power
		5	10	80	2	2	90	4	Neg	4	Legs power
		7	10	80	2	2	90	4	Neg		Arms power
	4	2	2	100	3	2	30	3	Neg	3	Legs explosive power
		4	2	100	3	2	30	3	Neg	4	Arms explosive power
		6	10	80	2	2	90	4	Neg	4	Legs power
		8	10	80	2	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/1st mezzo cycle/2nd week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume		Relief				Aim to be improved by Ex.
					Reps.	set	Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	
2nd	1	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	2	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power
	3	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	4	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/1st mezzo cycle/3rd week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume		Relief				Aim to be improved by Ex.
					Reps.	set	Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	
3rd	1	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	2	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power
	3	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	4	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/1st mezzo cycle/4th week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume		Relief				Aim to be improved by Ex.
					Reps.	set	Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	
4th	1	1	2	100	3	2	30	3	Neg	3	Legs explosive power
		3	2	100	3	2	30	3	Neg	4	Arms explosive power
		5	10	80	2	2	90	4	Neg	4	Legs power
		7	10	80	2	2	90	4	Neg		Arms power
	2	2	2	100	3	2	30	3	Neg	3	Legs explosive power
		4	2	100	3	2	30	3	Neg	4	Arms explosive power
		6	10	80	2	2	90	4	Neg	4	Legs power
		8	10	80	2	2	90	4	Neg		Arms power
	3	1	2	100	3	2	30	3	Neg	3	Legs explosive power
		3	2	100	3	2	30	3	Neg	4	Arms explosive power
		5	10	80	2	2	90	4	Neg	4	Legs power
		7	10	80	2	2	90	4	Neg		Arms power
	4	2	2	100	3	2	30	3	Neg	3	Legs explosive power
		4	2	100	3	2	30	3	Neg	4	Arms explosive power
		6	10	80	2	2	90	4	Neg	4	Legs power
		8	10	80	2	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/2nd mezzo cycle/5th week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume		Relief				Aim to be improved by Ex.
					Reps.	set	Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	
5th	1	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	2	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power
	3	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	4	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/2nd mezzo cycle/6th week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume Reps.	Volume set	Relief Among Reps(sec)	Relief Among sets (sec)	Relief type	Among Exs. (min)	Aim to be improved by Ex.
6th	1	1	2	100	5	2	30	3	Neg	3	Legs explosive power
		3	2	100	5	2	30	3	Neg	4	Arms explosive power
		5	10	80	4	2	90	4	Neg	4	Legs power
		7	10	80	4	2	90	4	Neg		Arms power
	2	2	2	100	5	2	30	3	Neg	3	Legs explosive power
		4	2	100	5	2	30	3	Neg	4	Arms explosive power
		6	10	80	4	2	90	4	Neg	4	Legs power
		8	10	80	4	2	90	4	Neg		Arms power
	3	1	2	100	5	2	30	3	Neg	3	Legs explosive power
		3	2	100	5	2	30	3	Neg	4	Arms explosive power
		5	10	80	4	2	90	4	Neg	4	Legs power
		7	10	80	4	2	90	4	Neg		Arms power
	4	2	2	100	5	2	30	3	Neg	3	Legs explosive power
		4	2	100	5	2	30	3	Neg	4	Arms explosive power
		6	10	80	4	2	90	4	Neg	4	Legs power
		8	10	80	4	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/2nd mezzo cycle/7th week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume		Relief				Aim to be improved by Ex.
					Reps.	set	Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	
7th	1	1	2	100	5	2	30	3	Neg	3	Legs explosive power
		3	2	100	5	2	30	3	Neg	4	Arms explosive power
		5	10	80	4	2	90	4	Neg	4	Legs power
		7	10	80	4	2	90	4	Neg		Arms power
	2	2	2	100	5	2	30	3	Neg	3	Legs explosive power
		4	2	100	5	2	30	3	Neg	4	Arms explosive power
		6	10	80	4	2	90	4	Neg	4	Legs power
		8	10	80	4	2	90	4	Neg		Arms power
	3	1	2	100	5	2	30	3	Neg	3	Legs explosive power
		3	2	100	5	2	30	3	Neg	4	Arms explosive power
		5	10	80	4	2	90	4	Neg	4	Legs power
		7	10	80	4	2	90	4	Neg		Arms power
	4	2	2	100	5	2	30	3	Neg	3	Legs explosive power
		4	2	100	5	2	30	3	Neg	4	Arms explosive power
		6	10	80	4	2	90	4	Neg	4	Legs power
		8	10	80	4	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Training program of the experimental group/2nd mezzo cycle/8th week

Week	Session	Ex. No	Ex.D (sec)	Ints. (%)	Volume		Relief				Aim to be improved by Ex.
					Reps.	set	Among Reps(sec)	Among sets (sec)	Relief type	Among Exs. (min)	
8th	1	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	2	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power
	3	1	2	100	4	2	30	3	Neg	3	Legs explosive power
		3	2	100	4	2	30	3	Neg	4	Arms explosive power
		5	10	80	3	2	90	4	Neg	4	Legs power
		7	10	80	3	2	90	4	Neg		Arms power
	4	2	2	100	4	2	30	3	Neg	3	Legs explosive power
		4	2	100	4	2	30	3	Neg	4	Arms explosive power
		6	10	80	3	2	90	4	Neg	4	Legs power
		8	10	80	3	2	90	4	Neg		Arms power

Note. Ex, = Exercise, No= Number, Reps. = Repetitions, Ints. = Intensity, D= Duration, Neg= Negative.

Appendix J. Arabic version of the expertise questionnaire

Goodness of training program

جامعة قبرص

كلية التربية الرياضية

الدراسات العليا

أنموذج استبيان للتعرف على مدى صلاحية البرنامج التدريبي

الأستاذ الفاضل .... المحترم

السلام عليكم... يروم الباحث إجراء بحثه الموسوم " تأثير تمرينات البليومتريك في مهارة التصويب من القفزعاليا وصفتي القوة الانفجارية والقوة المميزة بالسرعة للاعبي كرة اليد فئة الناشئين (تحت 16 سنة)" على عينة من فئة الناشئين ويهدف البحث الكشف عن اثر تمرينات البليومتريك على القوة الانفجارية والقوة المميزة بالسرعة للذراعين والرجلين وعلى التصويب من القفز، ونظرا لما تتمتعون به من خبرة علمية وعملية في مجالي التدريب الرياضي وكرة اليد يرجى بيان رأيكم في مدى صلاحية صلاحية البرنامج التدريبي المقترح وابداء الملاحظات التي ترونها مناسبة لتحقيق أهداف البحث .

شاكرين حسن تعاونكم

الاسم الكامل :

اللقب العلمي :

التخصص :

الكلية والجامعة :

التأريخ :

التوقيع :

طالب الماجستير

هاريوان عابد طاهر

النقاط التي تم مراعاتها عند تنفيذ البرنامج التدريبي

1- بدء الوحدات التدريبية بالإحماء العام لتهيئة كافة عضلات الجسم، ثم يليه إحماء خاص للعضلات العاملة في التمرين .

2- إنهاء الوحدات التدريبية بتمارين تهدئة واسترخاء للعضلات كافة .

3- تكون البرنامج التدريبي من (8) أسابيع (دورات صغرى) ويتم تنفيذها في دورتين متوسطتين وكل دورة متوسطة تحتوي على (4) دورات صغرى، ويكون تموج حركة الحمل في كل دورة متوسطة (1:3) .

4- احتوت كل دورة صغرى على (4) وحدات تدريبية يومية في الأسبوع، أي تنفذ كل مجموعة (32) وحدة تدريبية خلال المنهاج كله، ويتم اجراء الوحدات التدريبية اليومية في الدورات الصغرى في ايام (السبت والاثنين والاربعاء والخميس) اما باقي الايام فتكون بمثابة راحة للعينة .

5- تم أداء اربعة تمارين في كل وحدة تدريبية بحيث يكون التمرين الاول للقوة الانفجارية للرجلين والتمرين الثاني للقوة الانفجارية للذراعين والتمرين الثالث للقوة المميزة بالسرعة للرجلين والتمرين الرابع للقوة المميزة بالسرعة للذراعين

6- تم تنفيذ تمارين القوة الانفجارية للرجلين والذراعين بشدة 100 % وتمارين القوة االمميزة باالسرعة للرجلين والذراعين بشدة 80 %

7- تم تحديد زمن الراحة بين التكرارات وبين المجاميع من خلال التجربة الاستطلاعية، اذ كان زمن الراحة للقوة الانفجارية بين التكرارات (30 ثانية) وللقوة االمميزة بالسرعة (40 ثانية) وبين المجاميع كانت (3 دقائق) للقوة الانفجارية و (4 دقائق) للقوة االمميزة بالسرعة

8-تم التحكم بحمل التدريب (تموج الحمل) في كل دورة متوسطة بأستخدام التغيير بحجم الحمل (تكرارات ومجاميع)، فضلا عن اتباع مبدأ التكيف والتثبيت في الاسبوعين الثاني والثالث من كل دورة متوسطة وذالك بتثبيت الحجم .

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الاولى / الاسبوع الاول

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم: تكرار	الحجم: مجموعة	الراحة: بين التكرارات (ثانية)	الراحة: بين المجاميع (ثانية)	الراحة: نوع الراحة	الراحة: بين التمارين (دقيقة)	الهدف المراد تطويره من التمرين
الاول	1	1	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الاولى / الاسبوع الثاني الاسبوع الثان

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم: تكرار	الحجم: مجموعة	الراحة: بين التكرارات (ثانية)	الراحة: بين المجاميع (ثانية)	الراحة: نوع الراحة	الراحة: بين التمارين (دقيقة)	الهدف المراد تطويره من التمرين
الثاني	1	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الاولى / الاسبوع الثالث

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم		الراحة				الهدف المراد تطويره من التمرين
					تكرار	مجموعة	بين التكرارات (ثانية)	بين المجاميع (ثانية)	نوع الراحة	بين التمارين (دقيقة)	
الثالث	1	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الاولى / الاسبوع الرابع

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم		الراحة				الهدف المراد تطويره من التمرين
					تكرار	مجموعة	بين التكرارات (ثانية)	بين المجاميع (ثانية)	نوع الراحة	بين التمارين (دقيقة)	
الرابع	1	1	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	3	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	3	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	2	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	2	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الثانية / الاسبوع الخامس

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم		الراحة				الهدف المراد تطويره من التمرين
					تكرار	مجموعة	بين التكرارات (ثانية)	بين المجاميع (ثانية)	نوع الراحة	بين التمارين (دقيقة)	
الخامس	1	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الثانية / الاسبوع السادس

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم		الراحة				الهدف المراد تطويره من التمرين
					تكرار	مجموعة	بين التكرارات (ثانية)	بين المجاميع (ثانية)	نوع الراحة	بين التمارين (دقيقة)	
السادس	1	1	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الثانية / الاسبوع السابع

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم		الراحة				الهدف المراد تطويره من التمرين
					تكرار	مجموعة	بين التكرارات (ثانية)	بين المجاميع (ثانية)	نوع الراحة	بين التمارين (دقيقة)	
السابع	1	1	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	5	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	5	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	4	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	4	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

المنهاج التدريبي الخاص بالمجموعة التجريبية / الدورة المتوسطة الثانية / الاسبوع الثامن

الاسبوع	الوحدة	رقم التمرين	زمن التمرين (ثانية)	الشدة (%)	الحجم: تكرار	الحجم: مجموعة	الراحة: بين التكرارات (ثانية)	الراحة: بين المجاميع (ثانية)	الراحة: نوع الراحة	الراحة: بين التمارين (دقيقة)	الهدف المراد تطويره من التمرين
الثامن	1	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	2	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	3	1	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		3	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		5	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		7	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين
	4	2	2	100	4	2	30	3	سلبية	3	القوة الانفجارية للرجلين
		4	2	100	4	2	30	3	سلبية	4	القوة الانفجارية للذراعين
		6	10	80	3	2	90	4	سلبية	4	القوة المميزة بالسرعة للرجلين
		8	10	80	3	2	90	4	سلبية		القوة المميزة بالسرعة للذراعين

Appendix K. List of experts

Plyometric exercise and training program

F	Name	discipline	Job title	Institute
1.	Dr., Eyad Mohammed Abdullah	Science of coaching	Professor	College of physical education and sport sciences. University of Mosul
2.	Dr., Mutaz Younis Dhanoon	Science of coaching	Professor	College of basic education. University of Mosul
3.	Dr., Azad Ahmed Khaled	Science of coaching	Associated Professor	College of sport education, university of Dohuk
4.	Sadi Omer Yousef	Team handball	Associated Professor	College of sport education, university of Dohuk
5.	Dr., Yahya Mohamed Ali Mohammed	Team handball	Lecturer	College of basic education. University of Mosul

Appendix L. List of Work Team

f	Name	Job title	Institute
1.	Dulovan Asad Abdunabi	Assistant Lecturer	College of sport education, University of Dohuk
2.	Mahmood Salim Younes	Sport education bachelors	Sport institiution of Akre
3.	Awat Hussain Saleh	coach	Sumel Youth Center