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COMPARISON OF THE EFFECTS OF PLYOMETRIC AND RESISTANCE TRAINING ON SPEED, AGILITY AND EXPLOSIVE POWER: THE CASE OF GONDAR UNIVERSITY REGULAR SPORT SCIENCE STUDENTS

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JULAY, 2020

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A THESIS SUBMITED TO THE SCHOOL OF GRADUATE STUDIES OF BAHIR DAR UNIVERSITY SPORT ACADEMY IN PARTIAL FULLFILMENT OF THE REQUAIRMENT FOR THE DEGREE OF MASTERS OF SCIENCE IN COACHING ATHLETICES

BY

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APPROVAL OF THESIS FOR DEFENSE

I hereby certify that I have supervised, read, and evaluated this thesis titled "THE COMPARISON OF THE EFFECT OF PLYOMETRIC AND RESISTANCE TRAINING ON SPEED, AGILITY, AND EXPLOSIVE POWER ON THE CASE OF GONDAR UNIVERSITY REGULAR SPORT SCIENCE STUDENTS" by Abebe Getie prepared under my guidance. I recommend the thesis be submitted for oral defense.

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Adviser's Name	Signature	Date

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Approval of thesis for defense result

We hereby certify that we have examined this thesis entitled "COMPARISON OF THE EFFECTS OF PLYOMETRIC AND RESISTANCE TRAINING ON SPEED, AGILITY, and EXPLOSIVE POWER ON THE CASE OF GONDAR UNIVERSITY REGULAR SPORT SCIENCE STUDENTS" by Abebe Getie. We recommend that the thesis is approved for the Degree of Master of science in coaching Athletics.

Board of Examiners

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Chair person's Name	Signature	Date

DECLARATION

I, hereby that this thesis for the partial fulfillment of the requirement for the Degree of Master of Science in Coaching Athletics on the title of "THE COMPARISON OF THE EFFECTS OF PLYOMETRIC AND RESISTANCE TRAINING ON SPEED, AGILITY, AND EXPLOSIVE POWER IN THE CASE OF GONDAR UNIVERSITY REGULAR SPORT SCIENCE STUDENTS" is my real original work and all sources of materials used in this thesis have been acknowledged. It has not been previously conducted on the basis of award of any Degree, Diploma of any University, other Collages and other institution.

Mr. Abebe Getie	……………….	…………………….
Name	Signature	Date

Dedication

I dedicate this thesis manuscript to my beloved families and parents who had been besides me at everywhere, every time trough out my thesis work. As well as, my beloved and respected friends and peoples who contribute different advice, appreciation, and moral support for conducting successful thesis and reach in this stage.

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Lists of Abbreviations

CGs	Control Groups
EGs	Experimental Groups
EMG	Electromyography
FT	Fast Twitch
GRF	Ground Reaction Force
HSRT	High Speed Resistance Training
LTAD	Long Term Athletes Development
MVC	Maximum Volitional Contraction
PG	Plyometric Group
PT	Plyometric Training
RG	Resistance Group
RST	Resisted Sprint Training
RT	Resistance Training
SSC	Stretch -Shortening Cycle
ST	Slow Twitch

ABSTRACT

Some studies investigate the effect of different training programs on physical abilities. These studies typically aim to examine what training programs may improve what physical fitness components in athletes. It is crucial to set up proper training programs consistent with the motor needs and physiological properties of every sport. Jumping power, speed, and agility are invariably considered as significant factors in performing many sports skills. The purpose of this study is to investigate the comparative effects of plyometric and resistance training on speed, agility, and explosive power. This study has employed experimental research design. In this study, 40 Male Gondar University sport science students (10 samples out of 22 second year Male students and 30 samples out of 59 third year Male students) with the age of (PG=21.77 ± 1.30, RG=22.30 ± 1.04 and CG=21.93 ± 1.33) were assigned into three groups through stratified and proportional simple random sampling technique. Out of the three groups, two of them are assigned as experimental groups and the rest as control group. Both experimental groups (PG, N=13 and RG, N=13) participated in 8 weeks of plyometric and resistance training respectively. But the control group (N=14) did not participate in any of training. The experimental groups were manipulated 8 weeks training 3 days per week, each session lasting 50-80 minutes. Data were collected through pre and posttest measurements of each fitness test like flying 30 m speed, agility t-test, and vertical jump test. Collected data from the study was analyzed through the use of SPSS version 23 software program. The inferential data analysis methods such as paired t-test and independent sample t-test with level of significant p<0.05 were used to conduct the study. The result in the study shown that the interventions of 8 weeks plyometric and resistance training significantly improved the speed, agility, and explosive power of the students p<.05. The plyometric training group significantly improves the speed, agility, and explosive power of students than resistance training p<.05. Among plyometric and resistance training, plyometric training has been found better to improve the aforementioned fitness variables. So the researcher recommended that, it is better to use plyometric training rather than resistance training to gain better improvement of speed, agility, and explosive power.

Keywords*: Plyometric Training, Resistance Training, Speed, Agility, Explosive Power*

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

A variety of studies have been conducted on physical education and sports sciences in the world. Some studies investigate the effect of different training programs on physical abilities. These studies typically aim to examine the training programs that may improve specific physical skills in athletes. In principle, exercise training increases motor skills in humans. In this regard, it is crucial to set up proper training programs consistent with the motor needs and physiological properties of every sport. Power is invariably considered as significant factors in performing many sports skills (Chu, 1999). Sports experts suggest that weight (resistance) training and plyometric workout are two training methods that improve athletes' power and skills (Robinson, 2002). From among modern training methods, greater attention has paid to muscular fitness exercises. Plyometric exercises hinge on a set of mechanical and physiological skills and abilities (Bumpa, 2005). Plyometric is a type of explosive training that was first used by Russian athletes in the 1960 summer Olympics (Robinson, 2002). Plyometric training was established by Russian coach, Yuri Verkhoshansky, who used this type of training with jumpers (Rodcliff, 2000). It is a type of neuromuscular training used to increase explosive power, which enables athletes to use their maximum power in minimum time (Chukragel, 1983).

Plyometric, also known as jump training or ploys, are exercises in which muscles exert maximum force in short intervals of time, with the goal of increasing power (speed-strength). This training focuses on learning to move from a muscle extension to a contraction in a rapid or "explosive" manner, such as in specialized repeated jumping (Donald, 1998). Plyometric is primarily used by athletes, especially martial artists, sprinters and high jumpers (Starks & Joe 2013) to improve performance and are used in the fitness field to a much lesser degree (Yessis, 2013). Researchers have shown that plyometric training, when used with a periodized the strength-training program, can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness, and overall proprioception (Adams, O'Shea, O'Shea, K.L & Climstein, 1992). Plyometric is training techniques used by athletes in all types of sports to increase strength and explosiveness (Chu, 1998). The PT programme typically includes sport-specific exercises including exercises for shoulder and muscles of arms and has traditionally been used for sprinting, jumping, and sports with rapid changes in direction (Wang & Zhang, 2016).

Resistance training is also known as strength or weight training has become one of the most popular forms of exercise both for enhancing an individual's physical fitness and conditioning athletes. The terms of strength, weight, and resistance training have all been used to describe a type of exercise that requires the body's musculature to move (or attempt to move) against an opposing force. Individuals who participate in resistance training the program expects the program to produce certain benefits, such as increased strength, increased muscle size, improved sports performance, increased fat-free mass, and decreased body fat (Nobuko, Michael, Patrick, Gallaway & Pelin, 2015).

Resistance training is any exercise that causes the muscles to contract against an external resistance with the expectation of increases in strength, power, hypertrophy, and/or endurance. The external resistance can be dumbbells, barbells, kettle bells, resistance bands, exercise tubing, your own body weight, bricks, bottles of water, or any other object that causes the muscles to contract. Resistance exercise is any form of exercise that forces your skeletal muscles (not the involuntary muscles of your heart, lungs, etc.) to contract. An external resistance (such as heavyweights) is used to cause the contractions, and those contractions lead to increases in muscular mass, strength, endurance, and tone. As long as the weight causes muscular contractions, it counts as resistance exercise. There are several styles of resistance exercise. There is Olympic lifting (where athletes lift the weight overhead as you see in the Olympics), powerlifting (a competition where athletes perform the squat, deadlift, and bench press), and weight lifting (a sport where athletes lift heavy weights—typically fewer than six reps). When you lift weights at the gym to get stronger or bigger or more toned, you are performing resistance exercise. Occasionally you will hear the term "strength training" associated with lifting weights. Technically, it's incorrect to refer to resistance exercises like strength training. Instead, strength training would more accurately be described as resistance exercise that builds strength. In this article, the term resistance exercise will refer to the general type of weight lifting that you do in the gym to get bigger, stronger, more toned, or to increase your muscular endurance (Richard, 2019).

Although improvements in performance after resistance training is most marked for tasks with movement patterns similar to the resistance training exercises themselves, increases in velocity-specific performance has been shown when the testing and training exercises have been deferent (Wilson et al, 1993; Delecluse et al, 1995; Hoþ & Almasbakk, 1995). This suggests that resistance training exercises that significantly increase high-velocity force production may improve performance in other power-oriented tasks. It is reasonable to assume, therefore, that speed or power athletes wishing to improve their high-velocity force production should perform resistance training exercises at high movement speeds. In addition to resistance training, many athletes complete other training components (e.g. running, cycling, jumping) concurrently. Resistance training is a modality of the exercise that has grown in popularity over the past two decades, particularly for its role in improving athletic performance by increasing muscular strength, power and speed, hypertrophy, local muscular endurance, motor performance, balance, and coordination (Kraemer & Ratamess, 2000). It is frequently incorporated into the daily routines of recreationally active individuals and is also used by coaches and athletes to effectively improve strength, power and speed, balance, coordination, agility, muscle hypertrophy and motor performance (Kraemer, Adams, Cafarelli, Dudley, Dooly & et al, 2002; Kraemer et al, 2000).

Resistance training has also become an essential method to improve athletes" speed, agility, and explosive power. Research results show that resistance training improves explosive power, vertical jump and speed in professional soccer players by affecting the leg extensor muscles (Chelly, Ghenem, Abid, Hermassi, Tabka & Shephard, 2010). Miller, Herniman and Ricard (2006) in a study investigated the effect of six weeks of plyometric training on young athletes' agility observed significant improvements. In another study, Shahidi, Mahmoudlu, Mohammad, and Lotfi (2012) examined the “effects of eight weeks of resistance training on speed and explosive power in male soccer players” and observed significant improvements in these variables. Agility, speed and explosive power are qualifying components of physical fitness and desirable athletic performance, and play a key role in most sports. Plyometric and resistance training can be a prerequisite for coaches' and athletes' success (Zearei, Ramezanpourb & Pakdelanc, 2013). Therefore, the aim of the study was to investigate the comparison of the effect of plyometric and resistance training on speed, agility, and explosive power.

1.2 STATEMENT OF THE PROBLEM

Research results showed that heavy strength training on leg extensor muscles improved power, jumping height and sprint performance in professional athletes (McBride, 2002). Plyometric training is a widely used method to improve muscles' ability to generate explosive power. PT, in which a muscle is loaded and then contracted in rapid sequence, use the strength, elasticity and innervations of muscle and surrounding tissues to jump higher, run faster, throw farther, or hit harder, depending on the desired training goal (Baechle and Earle, 2000). PT has been shown to increase power, jumping height and sprint performance (Kotzamanidis, 2005; Wilson, Newton, Murphy & Humphries, 1993). Resistance training is a modality of exercise that particularly for its role in improving athletic performance by increasing muscular agility, strength, power and speed (Kraemer & Ratamess, 2004). Resistance training in this study consists of two specific training, strength training to increase strength and power training to increase power and speed.

Currently, it is well-established that RT as well as plyometric/sprint training is safe and appropriate tools for improving physical fitness of sedentary youth (Ingle et al., 2006) athletes (Diallo, Dore, Duche, & Van Praagh, 2001; Kotzamanidis, 2006; Thomas et al, 2009; Michailidis et al, 2013; Sohnlein et al, 2014; de Villarreal et al, 2015). Lenhart, Lamrova & Elfmark (2009) in study investigated the effect of eight weeks of plyometric training on speed and explosive power of volleyball players and observed significant improvements in these variables values (Lehnert et al, 2009). Bal et al (2011) in a study examined the effects of plyometric exercises on agility of youth basketball players and observed significant improvements (Bal et al., 2011). The contradictory studies have demonstrated no change in jump height after a six-week plyometric training (Gottlieb, Eliakim, Shalom, Dello-Iacono & Meckel, 2014) and 9-week training programme supplemented with plyometric exercises (Brito, Vasconcellos, Oliveira, Krustrup & Rebelo, 2014).

Surprisingly Vom Heede et al (2007) found a body weight/ elastic band resistance training to improve jump height more than a plyometric/ power training in male and female children (Vom Heede et al., 2007). Moreover, Chaouachi et al (2014) compared resistance training with plyometric training in male wrestlers and judo athletes and they found traditional resistance training to produce larger jump and sprint (e.g., 20-m sprint) improvements than plyometric training. Of note, traditional resistance training produced larger performance improvements compared with plyometric training. And also Miller, Herniman and Ricard (2006) in a study investigated the effect of six weeks of plyometric training on young athletes' agility observed significant improvements.

On the other hand, a recent review by Behm et al (2017) compared the effects of traditional resistance training with plyometric training in youth athletes and observed, greater improvements in jump height (power) due to plyometric, as well as greater improvements in strength and sprint measures due to resistance training. This study is in line with Mc Kinlay et al (2018) that plyometric training was more effective in improving jump performance than resistance training. Based on Saharuddin (2018), plyometric training group perform better on power and speed than the resistance training group and control group.

As the above statement shown that, different scholars postulated different conclusions about the effect of each training on speed, agility, and explosive power in case of athletes, youth projects, and different sport participants. Some said that plyometric training highly improves the fitness component than resistance trainings. And others also contradict this idea and they didn’t agree with other researcher idea. Due to this there are no well examined and concurrent (consistent) conclusions that examined, out of plyometric and resistance training, which training types merely (significantly) improve speed, agility, and explosive power in case of students performance. So in this study, the researcher was investigating the comparison of effects of plyometric and resistance training on speed, agility and explosive power in case of Gondar University regular Sport Science Students.

1.3 Objective of the Study

1.3.1 General Objective

The general objective of the study was to investigate the comparison of the effects of plyometric and resistance training on speed, agility, and explosive power.

1.3.2 Specific Objective

In order to investigate the study, the researcher has designed the following specific objectives.

1. To identify the effects of plyometric training on speed, agility, and explosive power.
2. To determine the effects of resistance training on speed, agility, and explosive power.
3. To compare the effects of plyometric and resistance training on speed, agility, and explosive power.
4. To determine among plyometric and resistance training, as better training approach to improve speed, agility and explosive power.

1.4 Hypothesis

The study has attempted the following hypothesis.

1. H1. 1: Plyometric training significantly improves speed, agility, and explosive power.
2. H0. 2: Plyometric training will not significantly improve speed, agility, and explosive power.
3. H1. 3: Resistance training significantly improves speed, agility, and explosive power.
4. H0. 4: Resistance training will not significantly improves speed, agility, and explosive power.
5. H1. 5: Plyometric training significantly improves speed, agility, and explosive power than resistance training.
6. H0. 6: Plyometric training will not significantly affect speed, agility, and explosive power than resistance training.

1.5 Significance of the Study

Investigating this study has the following significance.

- ➢ It will scrutinize the effects of plyometric and resistance training on speed, agility, and explosive power of students.
- ➢ It will determine among the two training types, which type of training will be recommended for the improvement of such physical quality (fitness variables) in the study.
- ➢ It will indicate the importance of different training types for athlete, coach, teacher, student, and other concerning body. Give directions in coaching, and teaching practice for the development of fitness.
- ➢ It will serve as the baseline for the other researcher for further study. Nowadays, there are so money researchers related to coaching and sport science discipline. So this study gives a clue for farther study.

1.6 Delimitation of the Study

In this study, the researcher has been investigating the effects of 8 weeks plyometric and resistance training on speed, agility, and explosive power on Gondar University regular sport science students. Even though there are so many athletics projects, clubs, post-graduate, and under-graduate sport science students in Ethiopia, it is difficult to examine the whole students, clubs, and projects because of budget, time, and effort. So in order to investigate this study, the researcher have been selected only Gondar University regular sport science Male students aged between 19 - 24. The study was conducted in the year of 2019-2020 G.C.

1.7 Limitation of the Study

During conducting this study, the following listed challenges were believed to affect the result of the study in one or another way.

- ✓ Mainly the absence of scientific test measurements like speed sense machine (timing gate). It is difficult to measure the exact time that the test is taken by using a stopwatch. Because the fraction of seconds that missed during the test affects the study.

- ✓ Lack of well-organized sporting clothes of the participant was also the other limitations of the study. Some Participants were used slippery shoes and non-stretched sporting clothe. This affects balance, speed, and freedom during fitness tests and training.
- ✓ Lack of the facility such as: elastic band for resistance workout, safe training arena to apply training for experimental groups are challenges this study.
- ✓ In addition to that, the absence of adequate budget was one factor. Since the research design of the study was experimental, it takes much money for participant diet, preparing training equipment and to buy other materials.
- ✓ Finally, the sever factor that affects this study is the global phenomena called CORONA VIRUS. Because of this vires, the researcher enforced to reduce the training plan from 12 to 8 weeks.

1.8 Operational Definition of Basic Terms

- ✓ Agility- rapid whole-body movement with change of velocity or direction in response to a stimulus (Sheppard, 2006).
- ✓ Explosive power- is movements that require a maximum or near-maximum power output from the athlete in a short amount of time.
- ✓ Plyometric - exercises in which muscles exert maximum force in short intervals of time, with the goal of increasing power (speed-strength).
- ✓ Resistance - an external force that resist the movement (locomotion) of something to oppose the movement.
- ✓ Speed- is the ability to reach a high velocity of movement in whatever mode of locomotion running, cycling, skating swimming, etc. (Baechle, 2000).

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Sport Training

It is understood as a process of systematic development of each component in dependence on the duration of preparation which leads to achieving maximum efficiency in senior age within the selected sports discipline. All activities which are part of human behavior were subject to long-term development. Let us take throwing, which is regarded as basic motor activity. Reaching maximum efficiency in any activity is not possible over a day. Efficiency is conditioned by several interrelated areas. Sports training focuses on reaching maximum efficiency in motor abilities connected to a certain sports discipline. Supposed performance depends on the motor ability and motor skills which are closely related to the sports discipline. Motor abilities can be described as relatively stable sets of inner genetic presuppositions needed to carry out locomotive activities. They include force, speed, endurance, coordination, and flexibility. Training for peak sporting performance includes training for physical development (general and sport-specific factors), and technical and tactical training (Bompa, 1999). To complete the requirements for achieving peak performance, athletes need to be healthy and free of injuries and have a theoretical knowledge of their training in preparation for their sport so that they can take some responsibility for their progress (Bompa, 1999).

To achieve high-performance levels in these physical qualities, training must start at an early age during long term athlete development. LTAD is a structured approach to the training of young athletes with one of the goals to maximize sporting talent by increasing the likelihood of+ developing a gifted child into a world-class athlete (Lloyd, Oliver, Faigenbaum, Howard, Croix & Williamset, 2015). For this purpose, Granacher et al (2016) recently introduced a conceptual training model for LTAD to promote the physical development of young athletes. Agility training, balance training, and plyometric training constitute major components of this model during different LTAD stages (e.g., Fundamentals, learning, and training to train).

2.2 Plyometric Training

Plyometric can be described as drills or exercises that are aimed at linking strength and speed of movement to produce an explosive-reactive type of movement often referred to as power. Plyometric exercises are thought to stimulate various changes in the neuromuscular system, enhancing the ability of the muscle groups to respond more quickly and powerfully to slight and rapid changes in muscular length. In general terms, plyometric training is one form of resistance training that involves the rapid stretching of a muscle(s) followed by a rapid concentric (shortening) contraction of the muscle(s) to produce a forceful movement over a short period. The aim is to develop the reactivity of the muscles. Plyometric training refers to a specific exercise modality that is built around jumping, hopping, bounding, and skipping movements. They are performed in an extremely fast and explosive manner (Lloyd, Oliver, Hughes & Williams, 2012).

Plyometric training results in more explosive, more powerful, and more rapid athletic movements. This means greater speed and acceleration, improved change of direction capacity, and better jumping performance (Michailidis, 2013). Plyometric training can improve power output, and then it should come as no surprise that it also can improve agility. With this in mind, research has shown that performing a plyometric training program consisting of two sessions per week, for as little as 6 weeks in total duration, can cause significant improvements in multiple measures of agility (Miller et al, 2006). Plyometric includes explosive exercises to activate the quick response and elastic properties of the major muscles. It was initially adopted by Soviet Olympians in the 1970s and then sporting worldwide. Sports using plyometric include basketball, tennis, badminton, squash, and volleyball as well as the various codes of football. The term "plyometric" was coined by Fred_Wilt after watching Soviet athletes prepare for their events in track and field (Wilt, Fred, Yessis &Michael, 1984).

Since its introduction in the early 1980s, two forms of plyometric have evolved. In the original version, created by Russian scientist Yuri Verkhoshansky, it was defined as the shock method (Yuri, 1966). In this, the athlete would drop down from a height and experience a "shock" upon landing. This in turn would bring about a forced eccentric contraction which was then immediately switched to a concentric contraction as the athlete jumped upward. The landing and takeoff were executed in an extremely short period; in the range of 0.1–0.2 seconds (Yuri, 1967). The second version of plyometric, seen to a greater extent in the United States, involves any form of jump regardless of execution time. The term plyometric became popular with the publication of books on the subject. Plyometric workout refers to those activities that permit a muscle fiber to create the greatest power at the least possible time. The sporting community acclaimed the benefits of plyometric training and incorporated in their protocols to enhance the performance in sports (Sivamani & Sultana, 2014).

Plyometric have been used for many decades in the Russian and eastern European training of track and field athletes (Chu, 1992). As previously observed in adults, significantly greater gains in performance may be observed when plyometric training is combined with resistance training (Adams et al, 1992; Almoslim, 2014; Fatouros et al, 2000). Strength training can increase force availability (Hermassi, Chelly, Fathloun, & Shephard, 2010; Hermassi, Chelly, Tabka, Shephard, & Chamari, 2011), but the high velocity training of plyometric may improve the rate of force development relative to traditional weight training (Herrero, Izquierdo, Maffiuletti, & Garcıa-Lopez, 2006). The strength training program, which included plyometric, sprinting, and resistance training, was also shown to provide a small but very likely benefit to maximal sprint speed which is an important anaerobic quality required for middle-distance running (Kadono & Enomoto, 2007).

Plyometric training provides the required stimuli and can enhance explosive contractions in both pubertal (Matavulj et al, 2001) and pre-pubertal (Litwiler et al, 1973) populations. Such a regimen is natural to many sports, with its emphasis on jumping, throwing, hopping, and skipping, and it is particularly appropriate where there is a need to develop explosive movements and vertical jumping ability, as in athletics. The stretching forces that occur during movement, give rise to eccentric muscle contractions with the resulting stored elastic energy, which contributes to an increase in strength in subsequent concentric contractions. This mechanism is known as the SSC (Komi, 2003; Nicol et al, 2006). Matavulj et al (2001) found that plyometric training improved jumping performance in teenage basketball players and Kotzamanidis (2006) reported that enhanced jumping performance and running velocity in pre-pubertal boys. However, plyometric training is not intended to be a stand-alone exercise program (Bompa, 2000; Chu et al, 2006).

Most athletes execute simple and complex jumps and call them plyometric rather than jump training as it was called in the past. This includes the depth jump which was executed in ways different from what was recommended by Verkhoshansky. This form of jump training is very popular but plyometric is a buzzword for all types of jumps, regardless of how long it takes to execute the jump. Its use is so pervasive that it is even possible to find push-ups described as being plyometric. Plyometric have been used for many decades in the Russian and eastern European training of track and field athletes (Chu, 1992).

Due to the wide use and appeal of the term plyometric, the true meaning of plyometric as developed by Verkhoshansky has for the most part been forgotten. Verkhoshansky was well known and respected worldwide in both the scientific and in the coaching arenas. He was relatively unknown in the United States except for some of his articles that were translated and published in the "Soviet Sports Review", later called the "Fitness and Sports Review International." In addition to creating the shock method, Verkhoshansky is credited with developing the stretch-shortening concept of muscle contractions and the development of specialized (dynamic correspondence) strength exercises. Plyometric, or more specifically the shock method, is considered a form of specialized strength development. Before undertaking plyometric training, it is necessary to distinguish jumps that are commonly called plyometric and true plyometric jumps as exemplified in the depth jump which is illustrative of the shock method. Since its inception in the former Soviet Union as the shock method, there have been other forms of the plyometric exercises created by Yessis that do not involve jump exercises. For details and illustrations of these exercises see "Explosive Running" (Michael & Yessis, 2000) and "Explosive Plyometric". These exercises involve the stretch-shorten concept that underlies the shock method.

The maximum platform height used by a high-level an athlete is no more than 40 inches (100 cm). Rather than developing greater explosive power, this height leads to more eccentric strength development. Going higher than 30 inches (76 cm) is usually counterproductive and may lead to injury. This occurs when the intensity of the forced involuntary eccentric contraction upon landing is greater than the muscles can withstand. Also, the athlete will not be able to execute a quick return (fast transition between muscular contractions), which is the key to the successful execution of explosive plyometric. Because of the forces involved and the quickness of execution, the central nervous system is strongly involved (Masalgin, 1987). It is important that the athlete not overdo using the shock plyometric method. Doing so will lead to great fatigue, and, according to Verkhoshansky, sleep disturbances. Athletes have great difficulty sleeping well if they execute too many depth jumps. This indicates that athletes must be well-prepared physically before doing this type of training (Yuri, 2011).

The most common type of plyometric used in the United States is simple and relatively easy jump exercises executed with little regard to execution time. These jumps are effective for athletes who execute skills in their sport that do not require explosive type muscular contractions. An example is long-distance running in which the runners execute repeat actions of 20 to 30 consecutive jumps and other cyclic-type activities such as leaping for multiple repetitions (Michael, 2000). Such plyometric jumps are also used as a warm-up for doing explosive plyometric jumps and for the initial preparation of the muscles before undertaking exercises such as depth jumps. In essence, they are effective in the early stages of learning how to do plyometric exercises and for preparing the muscles for explosive or quick jumps. These jumps are similar to those done by youngsters in the playground or neighborhood games and as such, do not require additional preparation. Athletes, regardless of their level of expertise, can undertake such jumps in the initial stages of training.

When athletes who have been doing plyometric without regard to time of execution first attempt to execute explosive plyometric, they often fail because the time of execution is too long. This occurs quite often in the depth jump. The athlete usually sinks (drops) too low which takes too long to make the transition from the eccentric to the concentric contraction. As a result, the exercise becomes a jump-strength exercise and not a true plyometric one. Jump technique remains the same regardless of whether it is a true plyometric exercise or a jump exercise. The hips, knees, and ankles flex when landing and the joints extend on the upward return. The sequence and overlapping in the sequence are the same, beginning with the hip extension, followed by knee extension, and ending with the ankle-plantar flexing. The major differences in execution are the depth of the landing and the time of executing the switch from the eccentric to the concentric contraction.

Studies have been conducted testing ten various plyometric exercises on overall performance during jumping examined by Electromyography, power, and GRF. Of the ten exercises, the single-leg cone hops, box jumps, tuck jumps, and two-legged vertical jumps produced the highest EMG values, alluding to greater motor recruitment. Power was examined in dumbbell jumps, depth jumps, countermovement jumps, squat jumps, and tuck jumps which all produced the higher power scale readings. In terms of athletic performance and training, the plyometric movements that utilize total body vibration produced an overall increase in performance output. A recent study examined two groups using the same plyometric protocol in combination with weight training, one using high loads and the other utilizing small loads, and similar decreases in power were found. This shows that the plyometric exercises themselves had a greater effect on the decrease in power output rather than the type of weight training (Beneka, 2012).

Many professional and Olympic athletes use plyometric training to improve muscular strength and jumping abilities which therefore increases their power. There are varying levels of intensity to plyometric. Another benefit of plyometric is that you can vary your level of intensity which means anyone looking to improve strength and jumping training can be involved regardless of fitness. With there being so many exercises this means you are less likely to get burned out and have a wide range of exercises to choose from. Another good reason with so many exercises being available is that you can find exercises that don't require the use of any equipment. It also increases muscular strength and endurance, also increases metabolic rate which increases weight loss and heart rate.

2.2.1 Physiological Basis of Plyometric Training

The contractile component of the actin and myosin cross bridges with the sarcomere play an important role in motor control and force development during plyometric. The plyometric movement uses the pre-stretch of the muscle-tendon unit a physiological length-tension curve in order to enhance the ability of the muscle fibers to generate more tension and resultant force production (Davies, 1992).

Rapid voluntary contractions of skeletal musculature are achieved via selective recruitment of motor units. It is generally accepted that the recruitment of muscle fibers follows an orderly pattern or sequence termed the size principle. Slow-twitch fibers are typically recruited at sub-maximal intensity efforts, and then as the intensity increases, the fast-twitch IIa fibers are recruited at approximately 30 percent up to about 80 percent of maximal intensity. At approximately 70-80 percent intensity, the fast-twitch IIa, IIb fibers are then recruited. Thus, plyometric need to be performed with high-intensity efforts, above 80 percent, to recruit the fast-twitch fibers that are crucial to power development. FT muscle fibers respond better to high-speed small-amplitude pre-stretch, therefore, the specificity of rehabilitation and performance enhancement via specific exercises, intensity, sets, and reps, are important in the design and execution of specific exercises (Davies, 1992).

2.2.2 Plyometric and Loaded Plyometric

Plyometric training typically involves jumping exercises; these exercises may begin from the feet only or also involve taking off from the hands such as is found in a plyometric pushup. Plyometric may also refer to exercises that involve similar quick movements of the body in a repetitive manner, such as repeatedly throwing a medicine ball in the air, catching it, and throwing it up again and so forth. Usually, an exercise is considered plyometric or not based upon its speed, the rapidity of its repetitions, and the extent to which it utilizes the body's stretch-shortening cycle. This cycle is where a muscle may be considered to alternately lengthen (an eccentric action) and then shorten (a concentric action) in quick succession during a repetition. The performance of repetitive jumps and sprinting both clearly emphasize the stretch-shortening cycle (Kent & Michael, 1998).

Loaded plyometric refers to the addition of a load, or weight, to jumping exercises. Jumping up and down with a trap bar for instance, or with a barbell held over the head. Loaded plyometric may increase explosive power more so than unloaded plyometric (Hansen, Derek, Kennelly & Steve, 2017). Two people can also co-operate in order to perform loaded plyometric exercises. For example, one person can carry the other on their back while they jump or hop.

Plyometric exercises are sometimes performed with an additional load, or weight added. The weight is held or worn. The additional weight may be in the form of a barbell, trap bar, dumbbells, or weighted vest. For instance, a vertical jump whilst holding a trap bar or jumping split squats whilst holding dumbbells. In addition, a regular weight lifting exercise is sometimes given a plyometric component, such as is found in a loaded jump squat. Jumping on to boxes or over hurdles whilst holding weights is not recommended for safety reasons. The advantage of loaded plyometric exercises is that they increase the overall force with which the exercise is performed. This can enhance the positive effect of the exercise and further increase the practitioner's ability to apply explosive power.

2.2.3 Plyometric and Speed Training

Plyometric exercise is a quick, powerful movement preceded by a pre-stretch, or countermovement, and involving the SSC (Wilk, Voight, Keirns, Gambetta, Andrews & Dillman, 1993). While speed is simply the ability to achieve high velocity, though its definition may be simpler, speed training also re-lies heavily on the SSC to elicit its desired outcome, that is, the achievement of higher velocity. The purpose of plyometric exercise is to use the stretch reflex and natural elastic components of both muscle and tendon to increase the power of subsequent movements; speed training exercises are designed to use these same mechanical and neurophysiological components, in concert with technique and muscular strength, to produce larger ground forces, thereby allowing clients to run faster. This chapter describes how to use plyometric and speed training exercise effectively as part of an overall training program.

2.2.4 Plyometric and Power Training

Plyometric training is a great way for athletes to build explosive power. Performing plyometric one to three times a week can increase your vertical jump and improve your speed and strength. The gains athletes make from plyometric training can directly translate to better performance on the field. Increased production of muscular power is an established outcome of participation in a plyometric training program (Asmussen, 1974). The ability to produce more muscular power has been associated with improved sports performance. Plyometric training, then, is an ideal exercise mode when the goal is to improve muscular power production. In addition to bringing about this increase in muscular power, plyometric training prepares athletes for the deceleration, acceleration and change-of-direction requirements in most sports by improving their ability to perform these types of tasks.

One of the best ways to train for explosive power and strength is by using plyometric. Plyometric was thought to be responsible for this superiority in track and field events. Plyometric is defined as exercises that enable muscle to develop maximum strength and power in a short period of time. The physiological basis of plyometric training is dependent on the amount of stretch placed on the muscle during an exercise. For example, if one were to jump off a 12-inch box, upon landing the muscle in the front of the thigh (quadriceps) would elongate and slow down the knee bending force acting as a shock absorber. However, if the muscle stretches too far, a mechanism within the muscle called the "stretch reflex" would facilitate the muscle to shorten thereby protecting the muscle from tearing apart. This coupling of the lengthening and shortening action of muscle takes place within hundredths of a second. Typically, the great high jumpers are on the ground a mere 0.12 seconds. In the plyometric terminology this is referred to as the amortization phase, the amount of time the foot is in contact with the ground after landing from jumping off a box and jumping on to another box. The shorter the time on the ground (amortization phase), the more explosive the muscle contraction and the greater gains in muscle strength. Surprisingly, although strength and innate speed is important, the length of the amortization phase is largely dependent on learning. Learning and skill training to strength the base can be the foundation of improving explosive leg power. Several important prerequisites to plyometric training are a good strength base, flexibility, and balance. The athlete entering into a plyometric program should be able to perform a power squat with 60% of body weight, perform a one-leg partial squat with good form and balance, perform a stork balance (one leg standing) with eyes open and eyes shut, have no knee pain, have no acute injuries to the foot and ankle, and should have a good landing surface. In addition, a good warm-up is necessary prior to plyometric training such as riding a bicycle or jogging for 5-10 minutes.

2.2.5 Plyometric Training Program Design

Plyometric exercise prescription is similar to resistance and aerobic exercise prescriptions (Chu, and Plummer, 1984). After an evaluation of the client's needs, the mode, intensity, frequency, duration, recovery, progression, and a warm-up period must all be included in the design of a sound plyometric training program. Unfortunately, there is little research demarcating optimal program variables for the design of plyometric exercise programs. Therefore, in addition to the available research, personal trainers must rely on the methodology used during the design of resistance and aerobic training programs and on practical experience when prescribing plyometric exercise. The guidelines that follow are based in part on Chu's work (Chu et al, 1984).

Neuromuscular overload

Applied loads and distances: with plyometric exercises, neuromuscular overload usually takes the form of a rapid change of direction of a limb or the entire body without external loads. The amount of total work in repetitions, sets, etc., and/or the range of motion (rom) the athlete moves through both contribute to the total overload amount.

Spatial overload

Range of motion: movements can have the effects of overload from the standpoint of rom. The rom can be performed throughout a larger range via an exaggerated movement pattern. The concept is to employ muscle activation and stretch reflex within a specific rom. As previously described, the reflexes mechanisms help facilitate the movement pattern to enhance force production.

Temporal overload

Timing: temporal overload can be accomplished by concentrating on executing the movement as rapidly and intensely as possible. The temporal overload, or keeping the time to rebound (amortization phase) as short as possible, is one of the keys to performing plyometric exercises for increased power production. A shorter time to rebound and electro-mechanical delay allows for effective force transmission from the eccentric pre-stretch to the concentric power performance phase of the plyometric movement.

Intensity

Intensity is the actual percentage of effort required by the athlete to perform the activity. In plyometric, the type of exercise performed controls the intensity. Plyometric exercises can come in many forms and intensities. Some activities such as bilateral jumping to a box are lower-level plyometric while others such as single-leg jumps from a box are intense. These variables must be considered when designing conditioning or rehabilitation programs.

Volume

Volume is the total work performed in a single work session or cycle (periodization). In the case of plyometric training, the volume is often measured by calculating the load, counting the number of repetitions, sets, etc. Fifty-foot contacts during a training session would be considered low volume, while 200 + would be considered high volume. Volume should be increased in a progressive manner to decrease the risk of injury or overtraining.

Frequency: frequency is the number of exercise sessions that take place during the training or rehabilitation cycle.

Recovery

Recovery is important to prevent injuries, overtraining, and to determine the primary emphasis of the plyometric program. Because of the intense demands on the body with plyometric training, longer recovery periods between sets may be appropriate. There is limited research on the optimum recovery times, but recovery between training sessions is usually 48 to 72 hours between exercise bouts with plyometric is recommended.

Specificity

Specificity in a plyometric program should be designed dependent upon the athlete's sport and position whenever possible to enhance the specific goals of the program and to replicate the athlete's given sport-specific activities. Specificity in plyometric training could include motions, angular velocities, loads, metabolic demands, etc. (Davies, Kraushar, Brinks & Jennings, 2006).

2.3 Resistance Training

Resistance training is a modality of exercise that particularly for its role in improving athletic performance by increasing muscular strength, power and speed (Kraemer & Ratamess, 2004). Resistance protocol is a style of workout focusing on the usage of resistance to persuade muscular shortening, which forms the power, muscular endurance, and size of voluntary muscles. Keeping this in mind, trainers, competitors, and physical education personnel have realized that resistance training methods became one of the best significant factors causing performance and resulting in the accomplishment of the particular actions in the competition or even improving the health status of a person. In addition, resistance training when integrated with plyometric training became the best common technique to progress in the areas of explosive power, maximum strength, and speed. It has been shown that jumps of various kinds can also precede the specific session of one's sport, with clear improvements on the various performances of jumping or running. In power development, the muscle and skeletal systems produce a powerful stimulus. The stress of this kind brings forth a broad mixture of physiological reactions and post-training adaptions, which in turn lead to developments in strength, hypertrophy, and power as examined throughout resistance based. Resistance training has been shown to increase strength and power, via accretion of contractile tissue and enhancement of neurological efficiency (Kraemer, Fleck & Evans, 1995; Schoenfeld, 2010).

2.3.1 High-Speed Resistance Training

HSRT is a relatively new approach to combat ailments associated with aging such as decreased muscle strength decreased functional performance and decreased quality of life. HSRT, which consists of fast, explosive movements, might be more effective than the more conventional low-speed resistance training in improving muscle strength and functional performance. Indeed, Ramirez-Campillo and colleagues have previously measured greater improvement in strength and functional performance in aging women following 12 weeks of HSRT compared to low-speed resistance training (Ramirez-Campillo, 2014).

2.3.2 Choosing Resistance Band

To start, it’s recommended that the lowest strength band. But, if you have been incorporating strength training into your routine regularly, you may be able to use a heavier resistance. To determine what that will be, perform a few of the exercises with different bands to find the one that you can stretch completely to the end of a move. For example: when performing a bicep curl, you are able to completely contract your arm and hold for a moment before lowering back to the starting position. (If the resistance of the band is too much for you to control and your arm is pulled back down in the other direction, the band is too heavy.

The lightest band in the pack is approximately the equivalent of a 5-pound dumbbell when stretched fully. However, what makes bands different than dumbbells is that the tension remains on the muscles during the entire exercise, whereas with dumbbells there is a part of the exercise where the muscle is not working. (For example, a bicep curl with band uses the bicep on the way up and way down; a bicep curl with dumbbell uses the bicep on the curl up and barely on the way down.)Once you’re able to do 10 repetitions with your starting band, you can increase to 15 repetitions. But it depends on the current fitness level of the trainer and accordingly with individual differences. Once that becomes too easy for your body, you can increase to the next band at an increased resistance level (from light to medium, or medium to heavy). Keep in mind that your lower body may progress to the next band before your upper body because the leg and glute muscles are larger and stronger than the upper body by design. (You may even start with a "light" band for upper body and "medium" for lower.)

2.3.3 Muscle Fiber Adaptation to Resistance Training

The increase in size of the muscle is referred to as hypertrophy. The 'pump' one feels from a single exercise bout is referred to as transient hypertrophy. This short term effect is attributable to the fluid accumulation, from blood plasma, in the intracellular and interstitial spaces of the muscle. In contrast, chronic hypertrophy refers to the increase in muscle size associated with long-term resistance training increases in the cross-sectional area of muscle fibers range from 20% to 45% in most training studies (Staron, Leonardi, Karapondo, Malicky, Falkel, Hagerman & Hikida, 1991). Muscle fiber hypertrophy has been shown to require more than 16 workouts to produce significant effects (Staron, Karapondo, Kraemer, Fry, Gordon, Falkel … Hikida, 1994). In addition, fast-twitch (glycolytic) muscle fiber has the potential to show greater increases in size as compared to slow-twitch (oxidative) muscle fiber (Hather, Tesch, Buchanan, & Dudley, 1991).

It is generally believed that the number of muscle fibers you have is established by birth and remains fixed throughout the rest of your life. Therefore, the hypertrophy adaptations are seen with resistance training are a net result of subcellular changes within the muscle which include: more and thicker actin and myosin protein filaments, more myofibrils (which embody the actin and myosin filaments), more sarcoplasm (the fluid in the muscle cell), and plausible increases in the connective tissue surrounding the muscle fibers (Wilmore & Costill, 1994).

2.3.4 Resistance training program design

The resistance training program is a composite of acute variables that include: muscle actions used, resistance used, volume (total number of sets and repetitions), exercises selected and workout structure (e.g., the number of muscle groups trained), the sequence of exercise performance, rest intervals between sets, repetition velocity, and training frequency (Fleck and Kraemer, 1997; Kraemer and Ratamess, 2000). Altering one or several of these variables will affect the training stimuli and potentially favor conditions by which numerous ways exist to vary resistance training programs and maintain/increase participant motivation. Therefore, proper resistance exercise prescription involves manipulation of each variable specific to the targeted goals (Kraemer & Ratames, 2004).

2.4 Speed Training

Speed is a quality that is always in high demand in sports. A major aspect of the job of strength and conditioning coach is the development and enhancement of the speed of players (Cissik, 2004; Young & Pryor, 2001). Kreighbaum and Barthels (1996) define speed as how fast a body is moving or the distance that is covered divided by the time it takes to cover that distance. From a biomechanical perspective speed is only a state of motion without regards to the direction.

Speed is the ability to reach a high velocity of movement in whatever mode of locomotion running, cycling, skating swimming, etc. (Baechle et al, 2000). Practicing, moving, and accelerating faster helps to condition the neuromuscular system to improve the firing patterns of fast-twitch muscle fibers. Two variations of basic speed training are assisted and resisted speed training. Assisted training (also called over-speed training helps to improve stride frequency. Resisted speed training helps to improve speed-strength and stride length (Mero, Komi, & Gregor, 1992).

To improve your running speed requires a training program that focuses on leg strength and power, with appropriate technical training to best utilize your strength and power development. Sprint training is not all about running fast. It is important to have a good fitness base to build speed upon and to have the capacity to train regularly. Specific sprint conditioning training would include working on speed endurance (alactic / lactic), maximum speed, elastic strength/acceleration, and reactive speed. The efficient sprinting technique does not always come naturally to everyone, can needs to be trained. Poor technique consumes excess energy in unnecessary actions and does not harness all power to direct the athlete in a forward direction at maximum speed. A lot of gains can be gained early on by concentrating on and modifying major flaws in technique. It is also important for some degree of relaxation while sprinting. Relaxation while running prevents the use of excess energy on non-speed related actions (Robert, 2010).

It is important to remember that the improvement of running speed is a complex process that is controlled by the brain and nervous system. For a runner to move more quickly the leg muscles have to contract more quickly, but the brain and nervous systems have to learn to control these faster movements efficiently. If you maintain some form of speed training throughout the year, your muscles and nervous system do not lose the feel of moving fast, and the brain will not have to re-learn the proper control patterns at a later date. In the training week, speed work should be carried out after a period of rest or light training. In a training session, speed work should be conducted after the warm-up, and any other training should be of a low-intensity (Karp, 2012).

2.4.1 The Components of Speed

There are two main factors in running speed, stride length and stride frequency (Cissik, 2004; Cissik, 2005; Lee & Ferrigno, 2005). For every athlete there is a unique balance between these two factors that will allow the athlete to run at the fastest speed possible. When training for speed development, a strength and conditioning coach attempts to manipulate stride length and frequency to develop an athlete's greatest speed potential. Stride frequency is the number of steps an athlete takes per minute or the number of strides taken over a certain distance. Stride length relates to the distance an athlete covers in one stride length, from the center of mass (Lee et al, 2005). Optimal stride length at maximum speed is normally 2.3 to 2.5 times an athlete's leg length (Lee et al, 2005). Optimal stride length is important because many athletes will over stride, and this leads to less force production (Baechle & Earle, 2000). There is a braking action of the legs which greatly decreases the rate of force production into the ground for forward propulsion. Athletes typically develop their optimal stride length through proper coaching of technique and improvements in strength and power, (Lee et al, 2005).

2.4.2 Sprint Training

Sprint training is usually meant in regard to running but may also include cycling or swimming. It is an effective means of training the body to be able to perform faster for longer. As well as increasing technical proficiency in that form of the sprint, it also develops overall power, cardiovascular capacity, and muscular endurance. The benefits of sprint training in terms of developing a greater power output can therefore help in the performance of other explosive power movements. It will usually be included in any comprehensive power training regime.

Another way of saying this is that the faster the switching from the eccentric to the concentric contraction, the greater will be the force produced and the greater the return movement. The speed of the switching is extremely fast, 0.20 seconds or less. For example, high-level sprinters execute the switch from the eccentric contraction that occurs when the foot hits the ground to the concentric contraction when the foot breaks contact with the ground in less than 0.10 seconds. In world-class sprinters, the time is approximately 0.08 seconds. Sprint training is an integral part of the overall training for track and field athletes, as well as field and court sports. Most sprint training focuses on drills and conditioning to develop acceleration and top speed straight sprinting (Blazevich, 1997a, 1997b; Delecluse, 1997; Donati, 1996; Francis, 1997; Knicker, 1997).

Plyometric training of the LEs been shown to increase sprinting speed or velocity (Chelly, Hermassi, Aouadi & Shephard, 2014). Sprinting velocity is important for sports requiring quick bursts of speed or repetitive change of direction. This is valuable for sports like soccer, handball, volleyball, and tennis. These studies included various forms of plyometric training ranging from three to 12 weeks in duration. Weekly dosage ranged from once per week to four times per week at most. A volume of greater than 80 jumps per session seems to result in the greatest benefit (Chelly et al, 2014). One consistent finding is that sprint performance improvement was not found to be significantly greater when plyometric exercises are performed combined with other types of exercises (such as plyometric + weight training) as compared to when they are performed alone. Lastly, the effects of plyometric training for sprint-specific programs appear to be the greatest over the initial portion of a sprint (10-40 m) as compared to longer distances (>40 m). These results suggest that sports participants who are accustomed to sprints over distances of 40 m could still improve times by improving in the initial acceleration phase of sprinting, by adding plyometric exercises to their program (Markovic, Jukic, Milanovic & Metikos, 2007). Controversy exists as several authors have not shown improvements in sprint times with plyometric training (Saez, Villarreal, Requena, Izquierdo & Gonzalez-Badillo, 2013).

2.4.3 Resisted Speed Training

Resisted speed training methods are often used to increase acceleration and maximal velocity. A quick first step is very critical for being able to make game-changing plays like blowing past defenders. Resisted speed training operates on the principle that when we work against a moderate amount of resistance, our muscles become stronger and are able to produce greater amounts of force, which in turn makes us faster when the resistance is removed. Being able to move faster, more powerfully and for a longer period of time is a simple recipe for success in athletics. One of the best ways to increase your acceleration, anaerobic endurance (short bursts of strength or speed) and lower-body power is through resistance band speed exercises. Resistance band speed exercises challenge your muscles to develop increased levels of power in natural, athletic movements. When the resistance bands are removed, you will be primed to move faster around the field. Also, resistance band exercises offer an additional challenge over their non-resisted counterparts, improving your conditioning so you can move at max speed even late in a game (Ryan, 2012). Resisted Sprint training is widely used to improve acceleration for athletes involved in speed and power events (Spinks, 2007). The primary aim is to enhance the strength levels of the lower limbs, specifically the hip extensors, while also emphasizing the kinematics of acceleration.

Resisted sprint training involves wearing a harness over the shoulders or around the waist and a form of resistance is applied backward as you propel yourself forwards. This can be in the form of a parachute, sled, bungee, or a partner with a resistance band. The idea is that you need to overcome the inertia of your own body plus the external load from your method of resistance. Research has shown mixed results with different methods but as a rule, resisted sprint training has been shown to improve an athlete’s acceleration over the first 10-20m of a sprint when performed properly (Ryan, 2012).

Resisted sprint training consists of executing sprinting exercises with additional overload, which is supposed to more effectively transfer to sports performance (Hrysomallis, 2012). Positive effects of resisted sprint training in sprinting have been demonstrated (Harrison & Bourke, 2009). But these results are controversial (Clark et al, 2010). In this respect, even though independent studies have demonstrated resisted sprint training to be more effective in un-resisted training (Harrison et al, 2009), a recent systematic review did not show any additional effect of resisted sprint training on acceleration (Petrakos, Morin & Egan, 2016). However, it is important to highlight that this review included studies implementing resisted sprint training exclusively by means of a weighted sled. Discrepancies in the literature may be, at least partially, attributed to different equipment's utilized (i.e.; weighted sled, weighted vests, parachute, elastic cables, etc.) or ineffective overload control during sprinting exercises, warranting the suggestion of a potential advantage of resisted sprint training over un-resisted training when appropriated overload control is provided. In fact, inaccurate overload control during resisted sprint training may affect movement technique, which has been demonstrated to compromise chronic training adaptations (Hrysomallis, 2012), emphasizing the essential role of overload control, and thus equipment selection, during the resisted sprint training.

2.4.4 Speed Training Program Design

As with plyometric exercise prescription, research on program design for speed training is sparse and therefore practical experience must be the guide. Speed training exercise prescription uses typical program design variables to provide a safe and effective plan to improve a client's speed. The mode of speed training is determined by the speed characteristics that the given drill is designed to improve. Speed training focuses on three areas: form, stride frequency, and stride length. Improving sprinting technique may be accomplished in a number of ways, including sprint performance, stride analysis, and specific form drills. Within an analysis of running speed, stride frequency, and stride length have an intimate relationship. In general, as both the stride frequency (the number of strides performed in a given amount of time) and stride length (the distance covered in one stride) increase, running speed improves. During the start, speed is highly dependent on stride length; as sprinting speed increases, frequency becomes the more important variable (Mero, et al; 1992). Of the two components, stride frequency is likely the more trainable, as stride length is highly dependent on body height and leg length. Stride frequency is typically increased through the use of sprint-assisted training, or running at speeds greater than a client is able to independently achieve (Costello, 1985).

Sprint-assisted training is an advanced technique that requires careful instruction and demonstration on the part of the personal trainer and clear understanding on the part of the client. Sprint assisted training may cause a client to alter his or her technique, which will affect running without assistance. Further, a proper warm-up to each session should be considered mandatory.

Resisted sprinting is used to help a client in-crease stride length, as well as speed-strength, by increasing the client's ground force production during the support phase, which is arguably the most important determinant of speed. Again, while maintaining proper form, clients may use upgrade sprinting or sprinting while being resisted by a sled, elastic tubing, or a parachute (Costello, 1985). Providing resistance to a construction worker by having the individual push a weighted implement or sled may improve his or her ability to push a wheelbarrow filled with cement. Although nearly all clients may perform form drills, sprint-assisted and -resisted training may be too advanced for some. A more general model of speed training that most clients can easily perform is interval sprinting. Specifically, a client sprints (or runs or walks, depending on abilities) as fast as possible over a given distance or for a predetermined amount of time, then rests. Following the rest period, the client repeats the bout. In performing interval training, clients are able to maintain higher-intensity work periods (i.e., sprint/run/walk) by interspersing them with times of rest (Fleck, 1983).

Intensity

Speed training intensity refers to the physical effort required during execution of a given drill, and is controlled both by the type of drill performed and by the distance covered. The intensity of speed training ranges from the low-level form drills to sprint-assisted and -resisted sprinting drills that apply significant stress to the body.

Frequency

Frequency, the number of speed training sessions per week, depends on the client's goals. As with other program variables, research is limited on the optimal frequency for speed training sessions;

again, personal trainers must rely on practical experience when determining the appropriate frequency. For clients who are athletes participating in a sport, two to four-speed sessions per week is common; non-athletic clients may benefit from one to two-speed sessions per week.

Recovery

Because speed training drills involve maximal efforts to improve speed and anaerobic power, complete, adequate recovery (the time between repetitions and sets) is required to ensure maximal effort with each repetition (Wathen, 1993). The time between repetitions is determined by a proper work-to-rest ratio (i.e., a range of 1:5 to 1:10) and is specific to the volume and type of drill being performed. That is, the higher the intensity of a drill, the more rest a client requires. Recovery for form training may be minimal, whereas rest between repetitions of down-grade running may last two to three minutes.

Volume

Speed training volume typically refers to the number of repetitions and sets performed during a given training session and are normally expressed as the distance covered. For example, a client beginning a speed training program may start with a 30-meter (33-yard) sprint but advance to 100 meters (109 yards) per repetition for the same drill. As with intensity, speed training volume should vary according to the client’s goals.

Progression

Speed training must follow the principles of progressive overload- systematic increase in training frequency, volume, and intensity through various combinations. Typically, as intensity increases, volume decreases. The program’s intensity should progress from:

- ✓ Low to moderate volume of low-intensity speed drills (e.g., stationary arm swing) to
- ✓ Low to moderate volumes of moderate-intensity (e.g., butt-kicker) to
- ✓ Low to moderate volumes of moderate to high intensity (e.g., downhill sprinting).

Warm-Up

As with any training program, the speed training session must begin with both general and specific warm-ups. The specific warm-up for speed training should consist of low-intensity, dynamic movements. Once mastered, many of the form drills provided at the end of this chapter may be incorporated into warm-up drills.

2.5 Agility Training

Agility is defined as an athlete's ability to move at an accelerated pace in one direction and then instantly decelerate and shift position within a matter of seconds. It is the one facet of sports training that can separate a good athlete from a great one. Whatever sports you engage in, these agility drills can improve your performance by strengthening the joints and muscles that go largely untested in daily life. As with any type of sports training, start slowly and focus on maintaining proper form. This will not only help you develop the stability (Ebben, 2010) needed to perform at your best, it can significantly reduce your risk of injury (Markström, 2019). To be agile, you are responding to what is going on around you, taking in that information and translating it into body positioning that will maintain balance and control. You are moving to the best position to take the next action, such as catching a ball or making a tackle. You are moving in a way that your body and sports equipment are in the right position to take the next action effectively (Paul, Gabbett & Nassis, 2016).

2.6 Power Training

Muscle power, which is a function of the interaction between force of contraction and the speed of contraction, is associated with the explosiveness of the muscle. The relationship between force and speed of contraction and the subsequent point at which peak power occurs varies between athletes (Jennings et al. 2005). For example, peak power occurs at 50–70% of the maximum weight that can be lifted for one repetition for the squat and at 40–60% of 1 RM for the bench press (Siegel et al. 2002). A fundamental way of increasing muscle power is to increase maximal strength, particularly in untrained athletes (Stone et al. 2000a).

Power training typically involves exercises which apply the maximum amount of force as fast as possible; on the basis that strength + speed = power (Kent et al, 1998). Jumping with weights or throwing weights are two examples of power training exercises. Regular weight training exercises such as the clean and jerk and power clean may also be considered as being power training exercises due to the explosive speed required to complete the lifts. Power training may also involve contrasting exercises such as heavy lifts and plyometric, known as complex training, in an attempt to combine the maximal lifting exertions with dynamic movements. This combination of a high strength exercise with a high-speed exercise may lead to an increased ability to apply power. Power training frequently specifically utilizes two physiological processes that increase in conjunction with one another during exercise. These are deep breathing, which results in increased intra-abdominal pressure; and post-activation potentiation, which is the enhanced activation of the nervous system and increased muscle fiber recruitment. Power training programs may be shaped to increase the trainee's ability to apply power in general, to meet sports-specific criteria or both.

2.6.1 Historical Examples of Power-Type Training

In terms of loaded plyometric and ballistic training, jumping with weights, either handheld or in the form of armor, and throwing the discus and javelin featured as part of sport and military training regimes in Ancient Greece. Amongst the heaviest known throws in antiquity, was a one-handed overhead throw of stone weighing 140 kg and which had a handle, by the Ancient Greek, Bybon. The record of this throw, which is sometimes translated as a lift, is inscribed onto the stone itself (Sweet, 1987). Throwing a stone was also a popular pastime and military training method in the medieval ages, with records of it including numerous depictions of a one-handed throw of a stone, roughly the size of a person's head, from the shoulder.

Ancient Persian and Indian wrestlers used to swing heavy wooden clubs, called Meels in Persian, or stone-topped wooden clubs, called Gads in India, in order to develop power. Notably, such exercises help to build strong and flexible joints. In a similar vein to contrast loading, the Romans trained with weapons which were double the weight of ordinary weapons, in order that when they used the ordinary weapons they would feel lighter and easier to use (Adkins, Lesley & Roy, 2004). In terms of heavy lifts, as a test of strength and manhood various societies, such as Celtic and Nordic ones, used to practice stone lifting. This involved lifting very heavy stones, usually over

100 kg, either up to their waist or onto their shoulder. Two examples are the Menzies stone (115 kg) in Scotland or the Husafell Stone (190 kg) in Iceland (Adkins et al, 2004).

2.6.2 Explosive Power Lifts

Explosive power lifts are weight training exercises which require a very fast movement to be performed by the lifter in order to lift the weight. For instance, in a power clean, a barbell is quickly lifted from the floor and unto the upper chest; this must be performed fast in one dynamic movement otherwise it would not be possible to move the weight to this position. Similarly, in a clean and jerk, a lifter moves a barbell to a position above their head whilst they quickly lower their height to allow for the easier extension of their arms; this movement must be performed in one very quick fluid action. If the lifter attempted to press the weight above their head slowly then they would not be able to. It is the dramatic increase in speed that allows for the lift to be completed and it is, therefore, an essential component.

2.6.3 Isometric Presses and Explosive Power Movements

Immediately prior to performing a powerful movement the body instinctively performs an isometric press in order to aid the subsequent power output. This is also known as isometric preload. An everyday example is when a person gets up off a chair. The person raises their posterior off the chair and forms an isometric press, involving the downward force of their torso onto their bent legs, which push upwards with an equal amount of force. From this point, the person then stands up. The isometric press which was generated by the torso and the legs helped them to preload their muscles so as to aid the subsequent move to stand up fully. A more dynamic example of this process can be found in a vertical jump. In this case, the jumper crouches down, generates an isometric press involving the downward force of their torso and the upward force of their bent legs, before powering upwards into the jump (Sharkey, Brian, Gaskill & Steven, 2007). Isometric presses may also be adapted to suit sports-specific requirements, such as in boxing. Here, a boxer may position their bodyweight primarily over their bent lead leg before throwing a lead hook. The force generated by the isometric press, involving the downward force of the torso and the upward force of the lead leg, is channeled into the subsequent punch making it more powerful (Dempsey, 1950). In athletic events such as sprinting, deliberate apparatus, called starting blocks, are used so the sprinters can perform a more powerful isometric press and channel this additional power into their first strides forwards: this ability to perform an enhanced isometric press allows them to start faster. Isometric presses may be performed faster or slower and in a variety of different ways but all perform the same role of isometrically preloading the muscles so a subsequent dynamic movement can be performed more powerfully. For this reason, isometric presses feature strongly in sports and athletics. The force they can generate can be increased through training and their instinctive usage can be encouraged through specific training of the associated musculature, such as that of the legs, hips, and core.

2.6.4 Explosive Power Development

Why does the same exercise prescription create different adaptations in different athletes? Why it is that if an athlete were to copy a training routine of an elite athlete it will not create the same adaptation for him/her as what it did for the elite athlete? The secret is that one should only use the general underlying fundamentals of these elite programs but adapt and apply it to suit each specific individual. Not all athletes have the same physical development of the components highlighted below and therefore also one of the reasons it is ideal to train various components throughout the training year as explained in the Window of explosive power development.

The figure below lists the 5 components necessary for the development of power. This basically means that if your athlete's weakest component is slow velocity strength you will get the biggest improvement by focusing on this component. To understand each component better the following examples of exercises that match each component is listed below;

- ✓ Slow velocity strength = Very Heavy Squats
- ✓ High velocity strength = Snatch (pulling the bar from the floor at high speed to an overhead position)
- ✓ Rate of force development = Speed squats (Doing a squat at 50%-60% of your MAX as fast as possible)
- ✓ Stretch shortening cycle = Jumping

- ✓ Inter and Intra-muscular co-ordination skill = This done during the teaching of techniques of lifts like doing drills of the exercises and focusing on getting the neuromuscular system to activate more muscle groups and muscle fibers to activate.

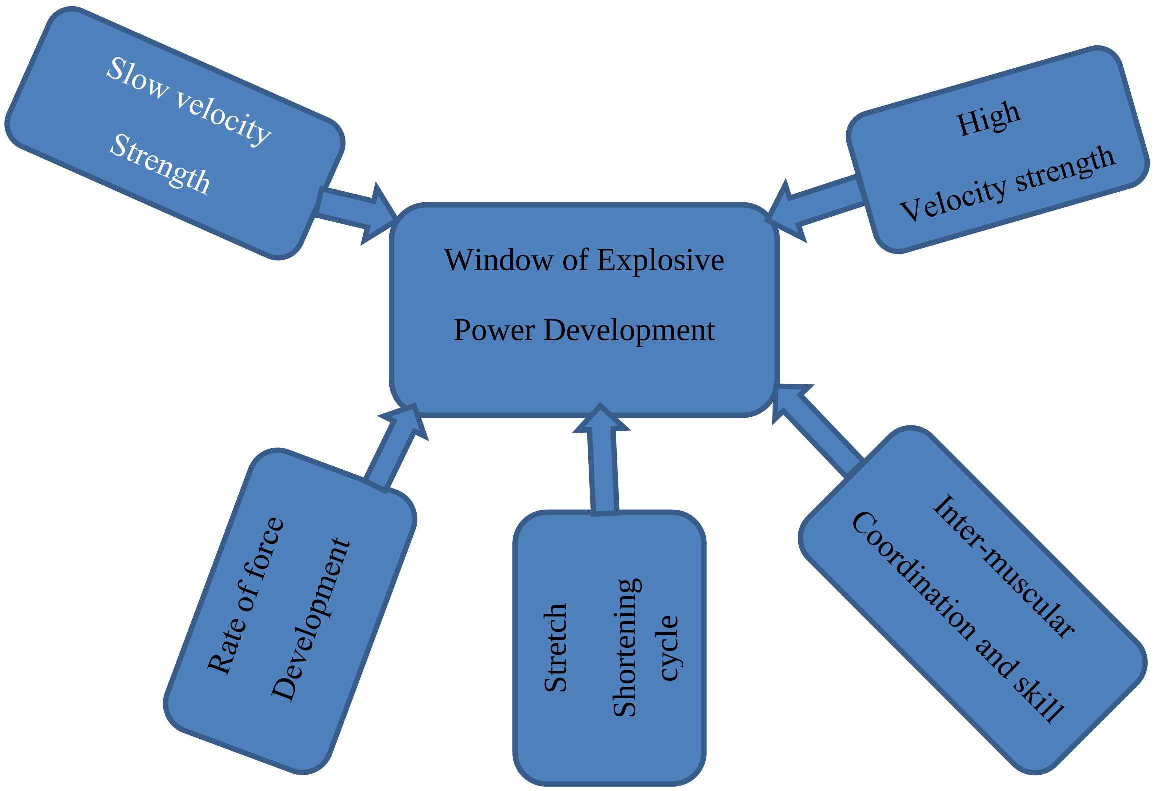

Figure 1 windows of explosive power development (Adapted from, Mcardle, Katch & Katch. (Fig 22.17, p 526)

The margin of adaptation gets bigger the weaker the component is that you are working on and the margin decreases the more developed the component is. The reason for this is that if you are already well-conditioned in slow velocity strength you will be close to your peak in that component and only small improvements will occur in your overall performance. These 5 components will differ from one person to another because of their genetic makeup, level of conditioning, previous training programs, and the sport they compete in. This is the reason why all these components should be trained throughout the season for athletes requiring explosive power in their sport. Explosive power is developed optimally by training all 5 components and if 1 of these de-trains it will have a detrimental effect on the athlete’s explosive power development. For example, if you become significantly weaker in slow velocity strength it may cause you to have a decrease in explosive power. The training modality that addresses almost all 5 of these components is Weight lifting or Olympic lifts. To appreciate the significant adaptation you can achieve with Olympic style weight lifting exercises, one first has to understand how the body works when creating a specific movement. In simple terms, it means that most sporting activities require the body to move as a unit combining.

2.7 The relationship between plyometric and resistance training

As we now and studies show success in sport is dependent on a number of training and environmental, technique, coordination, endurance, power, speed, flexibility, psychological skills, social skills, tactical skills, health, education of the athletes on the theory of sport, and cooperation in other socials facts, between other aspects (Alberto, 2014). Muscle strength and power with the ability to sprint and according to research appears to be related with the agility to change direction and the reactive force with the ability to engage the stretch shortening cycle also appears to contribute to the athlete ability to change direction pointed on some studies like (Gambetta, Kelly and Shepard, 2008). If you want to follow these principles you should develop strength using resistance like Split squat, resisted bridge, Donkey kicks, lateral leg lift, leg split and weight exercises like the squat, bench press, round to the front, and others, combining them with plyometric jumps and ensuring overall explosive force in a reduced number to avoid fatigue, can do 3-5 reps of each underwriting year with a total of 3-5 exercises each session and 3-5 series with adequate rest between 3-5 minutes and use stretching breaks (Alberto, 2014).

Resistance (weight) training and plyometric will be an important part of the speed, agility, power, and other fitness development program. The best results for strength and power gain are achieved when heavier loads are utilized during resistance training (Hass et al, 2001). Plyometric training is similar to any other kind of resistance training in that it involves a periodization of intensities from low to high as athletes improve their performance and ability (Baechle & Earle, 2000; Zatsiorsky, 2006).

The following diagram shoes the influence of plyometric and resistance training on such physical fitness variables and athletic performance.

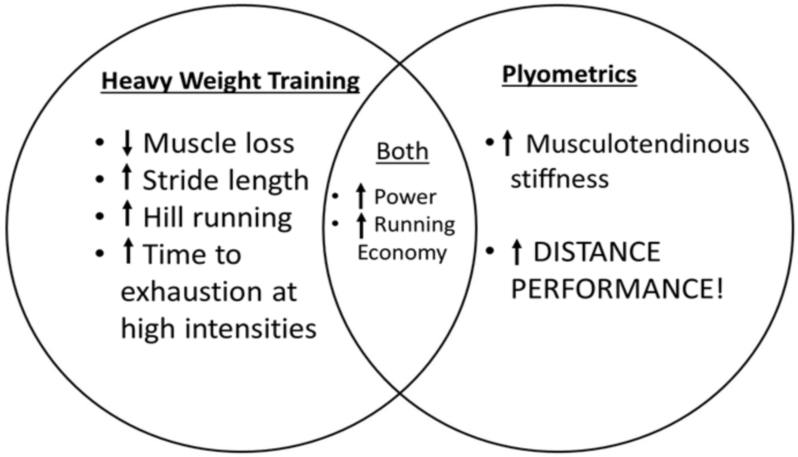

Figure 2 the relationship between plyometric and resistance training and their effect on fitness (retrived on 2020).

As shown the above diagram, applying plyometric and resistance (either free weight or weight machine) improves physical fitness components to develop the performance of sport participant. The purpose of plyometric exercises is to increase the power of these quick and powerful movements by enhancing the natural elastic components of the muscle tendon complex, as well as the stretch reflex (Baechle & Earle, 2000; Zatsiorsky, 2006). Whereas Resistance training increases muscle strength by making your muscles works against a weight or force.

CHAPTER THREE

RESEARCH METHODES

3.1 Geographical Location of the Study Area

The comparative study of the effect of plyometric and resistance training on speed, agility, and explosive power in the case of Gondar university sports science student was conducted in Gondar town particularly Gondar University Atse Tewodros Campus. Gondar formerly (Gwandar or Gwender) was the former capital city and it is the third city of Ethiopia. Located in the Semien Gondar Zone of the Amhara Region, Gondar is north of Tana Lake on the Lesser Angereb River and southwest of the Simien Mountains. Gondar, located in North West Ethiopia, is a city with a long tradition. It is also famous for its many medieval castles and the design and decoration of its churches - in particular, Debra Birhan Selassie which represents a masterpiece of the Gondarene School of art. It has a latitude and longitude of 12°36′N 37°28′E with an elevation of 2133 meters above sea level. It is surrounded by the Gondar Zuria woreda. Gondar served as a strong Christian kingdom for many years. Gondar has a population of 153,914 on 192.27 km^2 area according to 2015 G.C census statistics. Gondar previously served as the capital of both the Ethiopian Empire and the subsequent Begemder Province. The city holds the remains of several royal castles, including those in Fasil Ghebbi (the Royal Enclosure), for which Gondar has been called the "Camelot of Africa"(https://en.wikipedia.org/wiki/Gondar, 2020).

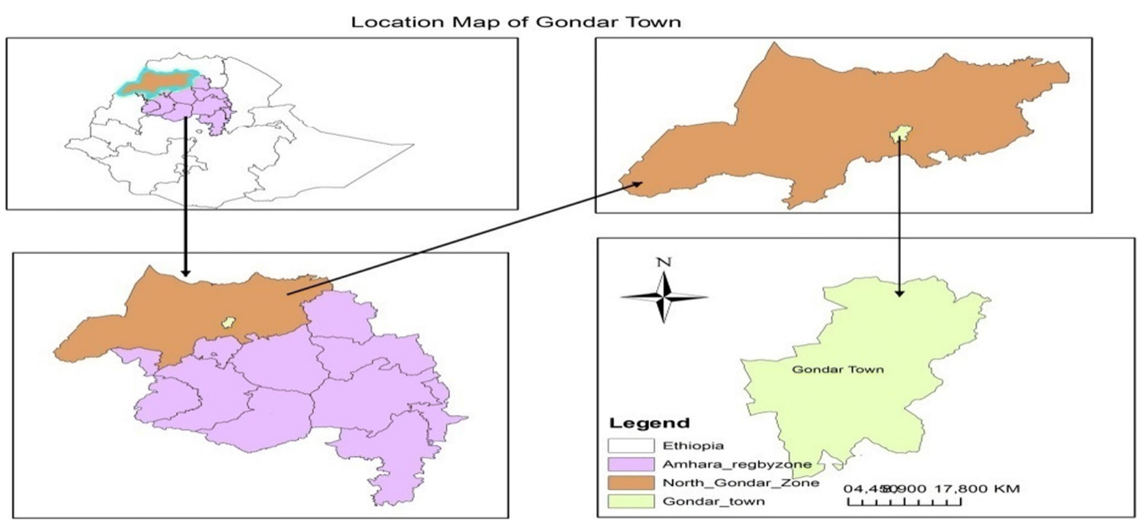

Figure 3 Maps of study area (Gondar)

3.2 Research Design

To investigate the effects of plyometric and resistance training on speed, agility, and explosive power, the researcher has employed experimental study design. This study design employed through an appropriate pre and post test results of the participant before and after trainings intervention for experimental groups and control group (without an intervention of training). Because in the quasi experimental study design, the cause and effect relationship among variables are examined. Both experimental groups participated their corresponding training session (3 day per week) as shown below.

Table 1Training program lay out of experimental groups

Treatment	Plyometric training	Resistance training
Training weeks	8	8
Session	3 days per week	3 days per week
Duration of session	50-80 minute	50-80 minute
Intensity	Low, moderate and high (progressively increase throughout the plan)	Low, moderate and high(progressively increase throughout the plan)
Exercise days	Monday , Wednesday, and Saturday	Tuesday, Thursday, and Saturday
Training time and place	Variety	Variety

3.3 Population, sampling technique and sample size

The study has been conducted at Gondar University, particularly Atse-Tewodros campus regular sport science students. In Gondar University, there are 81 Male and 112 Female, in total 193 regular sport science students. But to conduct the study, only Male regular sport science students were used. Since the study is experimental study design, it is difficult to conduct the study on all male sports science regular students due to lack of time, budget, and effort. So the researcher selected 40 samples from the total male students through stratified and simple random sampling technique.

In this study, the researcher grouped Male sport science students in to two stratum (second and third year students), and selected 10 samples from 22 second year Male students and 30 samples from 59 third year Male students through stratified and proportional simple random sampling technique. And also, proportional random sampling technique was used to balance equal number of students from each class year for plyometric, resistance, and control group. From those samples, 13 participants were for the plyometric group, 13 participants were for resistance group and the rest 14 participants also were selected for the control group by using a proportional random sampling technique. Both experimental groups were performed 8-week resistance and plyometric training for each (plyometric training for PG and resistance training for RG). The controlled group was not trained in additional training. For experimental groups, plyometric and resistance training for 8 weeks, 3 days per-week and 50-80 minute per-session were performed.

3.4 Source of Data

To conduct this study, mainly the primary source of data such as pre and post-test records of speed, agility, and explosive power tests were used. In addition, the secondary source of information like journals, related literature, and different articles was used in the study.

3.5 Data Collection Tools and procedures

Quantitative data were collected through the use of appropriate physical fitness test measures for each fitness component. Even though there are so many types of fitness tests for each, the researcher were used the following tests because of their effectiveness and validity. Such as flying 30 m sprint test for speed, agility T-test for agility and vertical jump test for explosive power. Before applying plyometric and resistance training for both EGs (PG and RG), the pre-test of fitness was performed for both CG and EGs. The post-test was also taken from all EGs and CG after completed 8 weeks of plyometric and resistance training of both EGs. Before recording pre and posttest measurements, adequate warming up was performed. In addition to this, different data collection materials like a cone, stopwatch, whistle, paper (record sheets), pen, pencil, meter, parker, and related materials were used.

The researcher used the following data collecting tests and procedures for each physical fitness variables in this study.

3.5.1 Speed test

Flying 30 Meter Sprint

Sprint or speed tests can be performed over varying distances, depending on the factors being tested and the relevance to the sport. This is the description of the 30-meter sprint test with a flying start. This is different from the 30m sprint test, which is measured from the blocks or a standing start. With a 30m running start, this test can measure maximum running speed. You can also perform this test as part of a 60m sprint test, using split times to measure the flying 30m time. This test is commonly used by track and field coaches as part of speed training.

Purpose: The aim of this test is to determine maximum running speed.

Equipment required: measuring tape or marked track, stopwatch or timing gates, cone markers, flat and clear surface of at least 80 meters.

Pre-test: Explain the test procedures to the subject. Perform screening of health risks and obtain informed consent. Prepare forms and record basic information such as age, height, body weight, gender, test conditions. Measure and mark out the test area. Perform an appropriate warm-up, including some practice starts and accelerations.

Procedure: Set up cones at 0, 30m and 60m along a straight line, and timing gates if available at 30m and 60m. The test involves a 30m acceleration area to enable the runner to get up to their maximum speed, then maximal sprinting over 30 meters. The tester should provide hints for maximizing speed (such as keeping low, driving hard with the arms and legs) and encourage them to continue running with maximum effort past the finish line.

Results: Two trials are allowed, and the best time is recorded to the nearest two decimal places. The timing starts from when the athlete's torso passes through the first timing gate, or by stopwatch when they pass the 30m cone, and finishes at the 60m cone marker. The flying 30m time can be used to predict 100m sprint times (Robert, 2019).

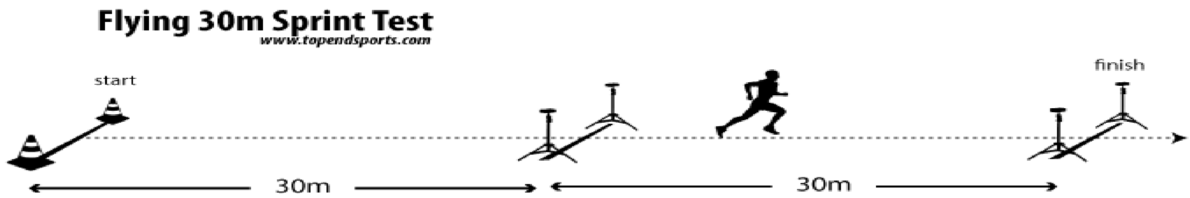

Figure 4 Flying 30 m speed test

3.5.2 Agility test

Agility T-test

The T-Test is a simple running test of agility, involving forward, lateral, and backward movements, appropriate to a wide range of sports.

Purpose: the T-Test is a test of agility for athletes, and includes forward, lateral, and backward running.

Equipment required: tape measure, marking cones, stopwatch, timing gates (optional)

Pre-test: Explain the test procedures to the subject. Perform screening of health risks and obtain informed consent. Prepare forms and record basic information such as age, height, body weight, gender, test conditions. Measure and mark out the test area. Perform an appropriate warm-up. See more details of pre-test procedures.

Procedures: Test setup: Set out four cones as illustrated in the diagram above (5 yards = 4.57 m, 10 yards = 9.14 m). The subject starts at cone A. On the command of the timer, the subject sprints to cone B and touches the base of the cone with their right hand. They then turn left and shuffle sideways to cone C, and also touch its base, this time with their left hand. Then shuffling sideways to the right to cone D and touching the base with the right hand. Then, they shuffle back to cone

B touching with the left hand and run back to cone A. The stopwatch is stopped as they pass cone A.

Scoring: The trial will not be counted if the subject crosses one foot in front of the

Other while shuffling, fails to touch the base of the cones, or fails to face forward throughout the test. Take the best time of three successful trials to the nearest 0.1 seconds (Pauole et al, 2000).

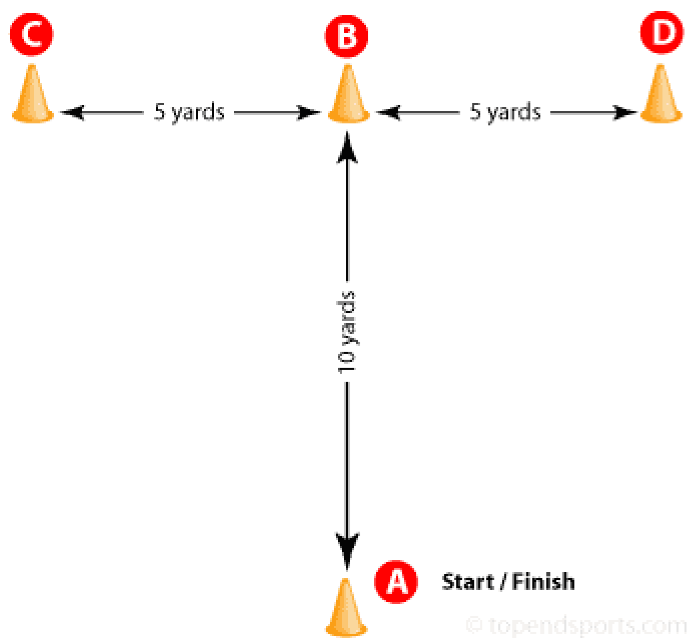

Figure 5 Agility t-test

3.5.3 Explosive power test

Vertical jump test

Objective: To measure the explosive power an athlete in vertical jump height jumped. **Equipment:** Measuring tape or marked wall, chalk for marking wall, score sheet, pencil.

Procedure: The player warms up for 10 minutes. The player chalks the end of her or his fingertips .The player stands side onto the wall, keeping both feet remaining on the ground, reaches up as high as possible with one hand and marks the wall with the tips of the fingers (M1). The player from a static position jumps as high as possible and marks the wall with the chalk on his fingers (M2). The assistant measures and records the distance between M1 and M2. The player performed three trials. The assistant calculated and recorded the highest jump from the three trials (Sargent, 1921).

Scoring: The jump height is usually recorded as a distance score in centimeter. See the vertical jump figures below.

Figure 6 Explosive power test

3.6 Methods of data analysis

Data analysis methods of this study were inferential statistics such as, T-test (paired sample-test) and an independent sample t-test. In this study there are two experimental groups (plyometric experimental group and resistance experimental group). Therefore, independent sample t-test has been used to compare the results between two groups. And also the paired sample T-test has been used to analysis the pre and post result of each experimental and control group. In order to made analysis of paired sample t-test and independent sample t-test, the researcher was manipulated Statistical Package for Social Science (SPSS) version 23 at 0.05 level of confidence.

3.7 Reliability of the test

The reliability and validity of the test in the study was assured by the necessary and effective fitness tests that are valid to each corresponding variables such as flying 30 m speed test for speed, agility T-test for agility, and vertical jump test for explosive power before and after the designed training. Before starting pre and posttest measurements, the necessary demonstration) were informed orally and practically about each test. Before pre and posttest measurements, adequate warming up was performed. And also the exact measurements of each fitness test were carefully used. In addition to this the same testing area (stadium), measurement unit, materials (cone, stopwatch), and time were used to ensure the uniformity of all groups in pre and posttest measurements. The investigator took all measurements in the study through several trials, with the assistance of professional experts in addition to advisor.

3.8 Ethical considerations

During conducting the study, the researcher has dealt ethical considerations to respect all the respondents and any participants in the study to keep psychological, physical and social harms. From starting pretest to posttest measurements, the researcher had an ethical and smooth relationship with respondents. This helps to motivate the participant and prevent the occurrence of risks such as injury during training. Furthermore, this study approved by an ethical review committee of Bahir Dar University sport academy post graduate studies to make sure it is not exposed to further risks. And the investigator has been address legal letters written by Bahir Dar University sport Academy to obtain permission from Gondar University sport science department and sport science students. All the participants had clear and successful information about the objectives, purpose of the study and procedures of the data gathering technique in each test.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

The purpose of this study was to investigate the comparison of the effects of 8 weeks plyometric and resistance training on some selected physical fitness components such as speed, agility & explosive power in the case of Gondar University regular sport science students.

This chapter deals with the analysis of the effect of plyometric and resistance training on such fitness variables. So it conducted the analysis of pre and post-test data collected from the plyometric experimental group (n=13), resistance experimental group (n=13), and control group (n=14) respondents. Between pre and posttests, there was an intervention of 8 weeks of training for both experimental groups. The collected data was analyzed using independent sample t-test (to compare the posttest result of plyometric and resistance group) and paired t-test (to compare the result of both experimental groups and control group of pre & posttest results in each fitness variables). To analyze the data collected through pre and posttests measurements, scientific methods of data analysis software Statistical Package for Social sciences SPSS version 23 were used.

4.2 Results of the study

Table 2 Demographic characteristics of participants

Group	N	sex	Age	Height	Weight	BMI
			Mean ± S.D	Mean ± S.D	Mean ± S.D	Mean ± S.D
PG	13	Male	21.77 ± 1.30	1.68 ± .03	62.15 ± 3.74	21.95 ± .90
RG	13	Male	22.30 ± 1.04	1.67 ± .06	62.38 ± 4.25	22.08 ± 1.44
CG	14	Male	21.93 ± 1.33	1.67 ± .05	62.07 ± 3.99	21.93 ± 1.33

Key: PG= Plyometric group, RG=Resistance Group & CG=Control Group and S.D=Standard Deviation

As shown from the above table, the descriptive characteristics of 40 study participant from Gondar university regular sport science students of the age (PG=21.77 ± 1.30, RG=22.30 ± 1.04 & CG=21.93 ± 1.33), height (PG=1.68 ± .03, RG=1.67 ± .06 & CG=1.67 ± .05), weight (PG=62.15±3.74, RG=62.38 ± 4.25 & CG=62.07 ± 3.99) & BMI (PG=21.95 ± .90, RG=22.08 ± 1.44 & CG=21.93 ± 1.33). This indicates that they have relatively similar height & weight but a little difference in age & BMI, especially PG and CG have a little difference from RG.

Table 3 Descriptive statistics of paired sample t-test of pre and post test results of plyometric, resistance, and control groups

Groups	Fitness	Paired comparisons	N	Mean ± Std. Deviation	Std. Error Mean
PG	Speed	Pre	13	4.0315±.16156	.04481
		Pos	13	3.1569±.17442	.04838
	Agility	Pre	13	11.4454±.24143	.06696
		Pos	13	10.2292±.25627	.07108
	Power	Pre	13	42.1692±1.77594	.49256
		Pos	13	47.0923±1.65301	.45846
RG	Speed	Pre	13	4.1535±.37187	.10314
		Pos	13	3.5796±.35169	.09754
	Agility	Pre	13	11.2750±.24535	.06805
		Pos	13	10.5596±.29734	.08247
	Power	Pre	13	41.9000±2.00707	.55666
		Pos	13	46.0385±1.53923	.42691
CG	Speed	Pre	14	3.9450±.33301	.08900
		Pos	14	3.8629±.42016	.11229
	Agility	Pre	14	11.3818±.68073	.18193
		Pos	14	11.2204±.72488	.19373
	Power	Pre	14	42.0571±2.44217	.65270
		Pos	14	42.3286±2.50551	.66963

Key: - PG=Plyometric Group, RG=Resistance Group, CG=Control Group, pre=pretest, Pos=posttest & power=explosive power

The above table showed that descriptive statistics result of the pre and posttest result for plyometric, resistance, and control groups in speed, agility, and power.

According to plyometric group, the mean and standard deviation of the pretest results of speed, agility and explosive power founds to be 4.0315±.16156, 11.4454±.24143 and 42.1692±1.77594 respectively. These results were, before the intervention of 8 weeks of plyometric training. After the manipulation of 8-week plyometric training (the post-test result), the result founds to be 3.1569±.17442, 10.2292±.25627, and 47.0923±1.65301 respectively. This shows the change of results in each fitness variable.

Based on the descriptive statistical results shown in the above table, mean value and standard deviation of speed, agility, and explosive power before an intervention for resistance group found to be 4.1535±.37187, 11.2750±.24535 and 41.9000±2.00707 respectively. But after the training, the result of speed, agility, and explosive power were 3.5796±.35169, 10.5596±.29734 and 46.0385±1.53923.

Mean and standard deviation of the control group's speed, agility and explosive power during pretest 3.9450±.33301, 11.3818±.68073, and 42.0571±2.44217 respectively were recorded. And after 8 weeks (they were not participating in any training), they also measured again (posttest) and showed almost similar results of speed, agility and explosive power (3.8629±.42016, 11.2204±.72488 and 42.3286±2.50551) respectively.

After the training was given, mean value speed and agility were reduced. It indicates the reduction of time (seconds) to cover the given tasks (test). Whereas the mean value of explosive power founds to be increased after 8 weeks of training manipulation, it revealed that the jumping ability of the participant has improved after 8 weeks of training as compared to the pretest.

Even though, there were result changes through the 8-week intervention of plyometric and resistance training on each fitness variables, we cannot conclude that there were statistically significant improvements in speed, agility, and power. This will analyze through the paired sample t-test results as shown below.

Table 4 The paired Sample Statistics of plyometric, resistance and control groups for speed agility and power.

Groups	Fitness	Pairs of groups	Paired Differences: MD	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper	t	Df	Sig. (2-tailed)
PG	Speed	Pre-Pos	.87462	.14118	.03916	.78930	.95993	22.337	12	.001
	Agility	Pre-Pos	1.21615	.36257	.10056	.99705	1.43525	12.094	12	.001
	Power	Pre-Pos	-4.92308	1.42018	.39389	-5.78129	-4.06487	-12.499	12	.001
RG	Speed	Pre-Pos	.57385	.18636	.05169	.46123	.68646	11.102	12	.001
	Agility	Pre-Pos	.71538	.14893	.04131	.62539	.80538	17.319	12	.001
	Power	Pre-Pos	-4.13846	1.25402	.34780	-4.89626	-3.38067	-11.899	12	.001
CG	Speed	Pre-Pos	.08214	.16767	.04481	-.01467	.17895	1.833	13	.090
	Agility	Pre-Pos	.16143	.19941	.05329	.04629	.27656	3.029	13	.010
	Power	Pre-Pos	-.27143	.58629	.15669	-.60994	.06709	-1.732	13	.107

Key: PG=Plyometric Group, RG=Resistance Group, CG=Control Group, pre=pretest, Pos=posttest, MD=Mean Difference, SD=Std. deviation, df =Degree of freedom and power=explosive power

The statistical analysis of paired sample t-test showed that there were statistically significant improvement of fitness variables in the study through the interventions of eight weeks of plyometric and resistance training.

According to a two tailed paired sample test result, speed (MD=.87462, SD=.14118), agility (MD=1.21615, SD= .36257) and power (MD=-4.92308, SD=1.42018) for both $P<0.001$ were found to be significantly improved through manipulation of eight weeks of plyometric training program. As the $p< 0.05$, the intervention of plyometric training significantly improve speed, agility (reduced time required to cover tests) and explosive power (by increasing jumping height) of the participants. So it revealed that t (12) = 22.337; $p<0.001$ (Table 4) for speed, t (12) = 12.094; $p<0.001$ (Table 4) for agility and t (12) = -12.499; $p<0.001$ (Table 4) for explosive power.

And also, based on the above table of a paired test of pre and posttest results, speed (MD=.57385, SD=.18636), agility (MD=.71538, SD=.14893) and power (MD= -4.13846, SD= 1.25402) and both $P<.001$ were significantly improved through the intervention of eight-week resistance training. These significant improvements in each physical fitness variables were t (12) = 11.102; $p<0.001$ (table 4) for speed, t (12) = 17.319; $p<0.001$ (Table 4) for agility and t (12) =-11.899; $p<0.001$ (Table 4) for explosive power. As the pair difference between pre and posttest result shown that there were better improvements in speed, agility, and power through 8-week resistance training. But, in control group except agility (MD =.16143, SD=.19941) p= 0.01 were significantly improved, without the intervention of any training (control group), speed (MD=.08214, SD=.16767, and p=0.090) and power (MD=-.27143, SD=.58629, and p=0.107) for both p>0.05 were not significantly improved. Because, they did not participate in any training interventions.

Table 5The descriptive statistics results of independent sample t-test for plyometric and resistance group in speed, agility and power

Fitness variable	Training groups	N	Mean	Std. Deviation	Std. Error Mean
Speed	PG	13	3.1569	.17442	.04838
	RG	13	3.5796	.35169	.09754
Agility	PG	13	10.2292	.25627	.07108
	RG	13	10.5596	.29734	.08247
Power	PG	13	47.0923	1.65301	.45846
	RG	13	46.0385	1.53923	.42691

Key: -PG= Plyometric Group, RG=Resistance Group

Based on the results in the above descriptive statistics table, physical fitness variables (speed, agility, and explosive power) for plyometric and resistance group has shown different values of mean and standard deviations. This reveals that among the 8 weeks plyometric and resistance training manipulation, the one training program significantly improved speed, agility and explosive power than the other.

Based on the result in descriptive statistics, the mean and standard deviation of the speed of participants (N=13) found to be PG= 3.1569±.17442 and RG=3.5796±.35169. And the mean and standard deviation of agility (N=13) also found to be PG=10.2292±.25627, RG=10.5596±.29734. In addition to that, the mean and standard deviation of power (N=13) founds to be PG=47.0923±1.65301 and RG=46.0385±1.53923. In this case, plyometric training improved the speed, agility power of the participant in the study than resistance training. As a result, the mean value of speed and agility were reduced when we compare PG to RG. This indicates that; time (Sec) that plyometric training groups were used to cover the distance of flying 30 m sprint (speed) and agility t-test (agility) were lower than that of the resistance training group. Whereas; the mean and the standard deviation of power of participants in plyometric training group was increased as compared to resistance groups. This shows that 8-week plyometric training increase the power of participants than the resistance group.

Even though there were the result difference in mean and standard deviations of speed, agility and explosive power between plyometric and resistance training group, we can't conclude that there was a significant improvement in fitness variables through plyometric training than resistance training. Rather use the following independent sample test statistics shown below.

Table 6 Independent sample test result of fitness variables in plyometric and resistance trainings

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
Fitness variable		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference (PG-RG)	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Speed	Equal variances assumed	2.779	.109	-3.882	24	.001	-.42269	.10888	-.64741	-.19798
	Equal variances not assumed			-3.882	17.567	.001	-.42269	.10888	-.65184	-.19354
Agility	Equal variances assumed	.172	.682	-3.035	24	.006	-.33038	.10887	-.55508	-.10569
	Equal variances not assumed			-3.035	23.489	.006	-.33038	.10887	-.55534	-.10543
Power	Equal variances assumed	.386	.540	1.682	24	.105	1.05385	.62645	-.23908	2.34677
	Equal variances not assumed			1.682	23.879	.106	1.05385	.62645	-.23942	2.34712

Based on the above descriptive statistical analysis (table 5) of independent sample test results, speed and agility were shown lower numbers of mean and standard deviation and power were shown a higher number of mean and standard deviation results of tests in 8 weeks plyometric training than resistance training manipulation. This showed that 8 weeks plyometric training was better improvement of fitness variables as compared to 8 weeks resistance training.

And also, according to an independent sample test statistical result, the MD of speed (-.42269) and p=.001; t (24) = -3.882, p=.001 (table 6) showed that plyometric was significantly improved the speed of participant than resistance training.

Based on the above table the result of MD of agility (-.33038) and p=.006; t (24) = -3.035, p=.006 showed plyometric training was significantly improved the agility of participants than resistance training. And the MD of explosive power (1.05385) and p=1.05 showed plyometric training was not significantly improved the power of participants than resistance training.

4.3 Discussions

The present study was designed to investigate the comparison of the effects of plyometric and resistance training on speed, agility, and explosive power in case of Gondar University regular sport science students. During the study, the participants were actively participated in every activity from pretest to posttest measurements in addition to general warming up workouts before pre and posttests in the study. Especially, PG and RG were seriously followed the intervention of 8-week training program. On the other hand, the control group was not participated in any training up to the end of the study except the pre and posttest measurements. But since the participants of this study were sport science students, both experimental and control groups have participated in common sports training given by their Teachers. The interventions of plyometric and resistance training were not parallel (collapse) to their class training. Rather used free training days. In this study, there were showed significant improvements through the intervention 8 week plyometric and resistance training programs as follows.

The findings of the study revealed that there were significance differences on physical fitness variables such as speed, agility and explosive power between pre and posttests results through the intervention of 8 weeks plyometric and resistance training. This difference that existed during an analysis of the study shows performance improvement in fitness variables.

Based on the results in the study, the mean and standard deviation of posttest results (3.1569±.17442) of speed was reduced through 8 weeks of plyometric training as compared to pretest (4.0315±.16156). And the MD=.87462, SD=.14118, and p<.001 shown that 8 weeks of plyometric training had improved the speed of participants at 0.05 level of confidence. Many papers have reported statistically significant and positive effects of a plyometric programme on sprint performance (Arazi and Asadi, 2011; Slimani, Chamari, Miarka, Vecchio & Chéour, 2016; Stojanović et al., 2016). In contrast, sprint running performance did not change after 4-week plyometric training conducted on grass root 18 amateur, adult soccer players (Impellizzeri, Rampinini, Castagna, Martino, Fiorini & Wisloff, 2008). A number of factors such as muscle length, strength, age, gender, temperature, body shape, force, and flexibility can have profound impacts on speed (Mokhtari, Rostami & motion, 2003). Probably plyometric exercises led to speed improvements by affecting muscle length, force, muscle temperature, strength, and flexibility during the eight weeks training. In addition to this, According to Söhnlein et al (2014), 2 PT sessions per week may be efficient to improve sprint performance. The main reason is that PT activates the stretch-shorting cycle (SSC) mechanism. The SSC is when the muscle is lengthened (eccentric phase) and then immediately after the lengthening the muscle is shortened (concentric phase) (McArdle et al., 2007; Komi 2000).

Based on the results in the study, mean and standard deviation of posttest results of agility (10.2292±.25627) had been reduced after 8 weeks of plyometric training as compared to pretest results (11.4454±.24143). This reduction change of results shows, through the plyometric training agility level of participants improved. The MD=1.21615, SD= .36257 and p<.001 reveled that, plyometric training significantly improved agility performance at 0.05 level of confidence. This is supported by Potteiger et al (1999) that states plyometric training improved times in the agility test measures because of enhanced motor unit recruitment patterns. Plyometric training affects muscle spindles, Golgi-tendon, tendons, joints, balance, and body position controlling (Miller, Herniman & Ricard et al, 2006). Maybe neuromuscular adaptations caused by plyometric exercises affects muscle spindles, Golgi tendon, tendons, joints, balance and body position controlling favorably and this led to agility improvement in these athletes. This was well supported by Craig (2004); Miller et al. (2001); Parsons et al. (1998); Yap et al. (2000); Young et al. (2001) study which justifies, Plyometric drills usually involve stopping, starting, and changing directions in an explosive manner and developing agility. A pervious article suggests that 6 weeks of plyometric training consisting of one session per week leads to significant improvements in the traditional agility test known as the T-test, Illinois Agility Test and force production (Miller et al. 2006).

According to the result of the study, the mean and standard deviation of the posttest recorded of power (47.0923±1.65301) had been increased after the interventions of 8 weeks plyometric training as compared to the pretest recorded result (42.1692±1.77594). This increment shows that the jumping performances of the participant were improved by plyometric training manipulation. And MD=-4.92308, SD=1.42018 and p<.001 directs, 8-week plyometric training was significantly improved power (vertical jumping performance) at 0.05 level of confidence. As the sign of MD indicates (negative sign), the jumping height of the pretest was lower than the posttest recorded (after training), improvement of power already existed. Multiple authors have demonstrated that plyometric training programs can increase maximal vertical jump height (Adams, O'Shea JP, O'Shea KL & Climstein, 1992). According to the study of Haghighi, Moghadasi, Nikseresht, Torkfar, Haghighi and Eur (2012), Plyometric is a training method, which is widely used to improve muscular strength to generate explosive power. This method led to increased explosive power in subjects by rapid strength production and nervous system improvement after eight weeks. In general, Shallaby (2010) states that, PT improved vertical Jump height, sprint speed, and agility in 16-year-old male players. Furthermore, a period of 10 weeks or more (more than 20 sessions of plyometric training in total) has been suggested to maximize the probability of obtaining significant performance improvements in athletes (Slimani et al, 2016). So plyometric training improved speed, agility, and explosive power of the students. Based on this, the researcher accepted hypothesis H1.1 and rejected Ho.2 at 0.05 level of confidence.

Based on the results in the study, the mean and standard deviation of speed that found after an intervention of 8 week's resistance training (3.5796±.35169) has been decreased as compared with results found before training (4.1535±.37187). This decrement of recorded test results indicates improvements in speed were found after the intervention of 8 weeks of resistance training. And also, the MD= .57385, S.D=.18636, and p<.001 indicates speed had been significantly improved at 0.05 level of confidence. According to Haghighi, Moghadasi, Nikseresht and Torkfar (2012), Research results show that resistance training improves speed in professional soccer players by affecting leg extensor muscles. Apart from increasing power, other factors such as muscle length and temperature, body shape and flexibility also should be noted in speedy performances. But the result of Shahidi et al (2012) study contradicts this idea.

Based on the results shown in the study, the mean and standard deviation results of agility that found after 8 weeks resistance training (10.5596±.29734) were lower than that existed before any interventions of resistance training (pretest recorded results) (11.2750±.24535). This shows that to cover the distance in agility t-test, study participants during the posttest takes smaller time (second) than during pretest. And the MD= .71538, SD=.14893 and p<.001 revealed that 8 weeks of resistance training significantly improved the agility of participants at 0.05 level of confidence. These results were consistent with Miller et al (2006) but did not match with Tartibyan, Mardani, Ravasi and Tolouei (2012). Agility along with other factors such as balance, coordination, speed, power, and reaction speed is one of the physical fitness factors related to skills (Lotfi & Gaeini, 2003). Probably, muscle fibers hypertrophy due to resistance training led to the subjects' ability to change situation and direction rapidly without losing precision and balance.

As analysis result revealed that, the recorded mean and a standard deviation of explosive power after resistance training (46.0385±1.53923) were higher than results that found before training (41.9000±2.00707). So, vertical jumping performances of student were improved through resistance training. And also the MD=-4.13846, SD=1.25402 between pre and posttest recorded result and p<.001 shows, an intervention of 8-week resistance training significantly improved the explosive power of students at 0.05 level of confidence. Since resistance training can provide athletes with the means to improve strength and power through both neural and physiological adaptation, this serves as a powerful argument for the concept that adolescent athletes should engage in some method of resistance training (Legerlotz et al., 2016). Adaptation to skeletal muscle can also occur as a result of the stress applied to the body from resistance training without any structural damage occurring (Legerlotz et al., 2016). Nerves adaptation improves strength in the first 3-4 weeks of resistance training. Muscle hypertrophy creates an increase in the size and function of muscle fibers after 8-12 weeks of resistance exercise. Probably neural adaptations and hypertrophy caused by resistance exercises, improved explosive power in these subjects (Johnson, Sburns & Azevedo, 2013). After the training was given, the mean value of speed and agility were reduced. It indicates the reduction of time (seconds) to cover the given tests in each fitness variables. Whereas the mean values of explosive power were increased after 8 weeks of resistance training, the jumping ability of the participant was improved after 8-week resistance training as compared to pretest. There is evidence that resistance training has the potential to improve muscular power, agility, balance and stability, coordination, and speed of movement in youth athletes (Harries, Lubans & Callister, 2012; Lesinski, Prieske & Granacher, 2016). Based on the results, resistance training significantly improved the speed, agility, and explosive power (p=001) of the students. So the researcher accepted hypothesis H1.3 and rejected Ho.4 at 0.05 level of confidence.

So, based on the above discussions about effects of plyometric and resistance training on physical fitness components (speed, agility, and explosive power), the intervention of 8 weeks plyometric and resistance training had been significantly improved (p<.001) speed, agility, and explosive power at 0.05 level of a confidence interval.

Whereas, as the mean and standard deviation of pre and posttest results of the control group shows that in each fitness variable, the changes that pretest compared with the posttest are very small. And except the result of agility, MD between pre and post results of speed and power are small and didn't statistically significant as p>0.05. But MD=.16143, SD= .19941, and p= .010 of agility shows that agility of the control group significantly improved as posttest compared to pretest. But a little improvement in each fitness variable shows that the repetition of the test leads to the adaptation of the participants during each fitness test and helps the participant easily perform the test during the posttest. In addition to that maturity of the individual may change this result. Especially, the main reason that the improvement of agility performance without training is that, agility t-test by nature needs psychological readiness before the test started and may easily change direction through adaptation without any training intervention. And agility is not a matter of quickness only; rather it's also better reaction time and development of psychological readiness.

From the above discussion, the plyometric and resistance training significantly improved the speed, agility, and explosive power of the students. But, the researcher didn't discuss, among plyometric and resistance training, which training groups are significantly improved and recommended for better improvement of physical fitness variables of the study (speed, agility, and explosive power). So, this comparing result conducted as follows below.

Based on the results that are shown in (table 5), the recorded mean and SD of speed and agility in plyometric training (M=3.1569, SD=.17442) & (M=10.2292, SD=.25627) were less than results in resistance training (M=3.5796, SD=.35169) and (M=10.5596, SD=.29734) respectively. This shows that students that perform 8-week plyometric training used less time (second) to cover flying

30 m sprint test and agility T-test than that participated in 8-week resistance training. And the MD (-.42269) for speed and (-.33038) for agility in (table 6) shows a negative sign. This indicates that students in plyometric training were recorded a smaller time to cover the corresponding fitness test than in resistance training. So the intervention of 8 weeks plyometric training significantly improved (p=.001 for speed and p=.006 for agility of students) than resistance training at 0.05 level of confidence. And the student's mean and standard deviation of explosive power that recorded after plyometric training (M=47.0923, SD=1.65301) was higher than the results recorded after resistance training (M=46.0385, SD=1.53923). This increment shows that students that manipulated 8-week plyometric training was jumped higher than that participated in 8 weeks of resistance training. The value of MD=1.05385 (table 6) also reveals that the intervention of 8 weeks plyometric training shows some improvement of explosive power than participating in resistance training, but it is not shown as much significant improvement as p=.105 which is greater than 0.05.

As a result of the mean shown, the mean value of speed and agility were reduced when we compare PG to RG. This indicates that; time (Sec) that plyometric training groups were used to cover the distance of flying 30 m sprint (speed) and agility t-test (agility) were lower than that of a resistance training group. Whereas; the mean and the standard deviation of power of participants in plyometric training was increased as compared to resistance groups. This shows that, 8-week plyometric training increases (some increment) the power of participants than the resistance group. This is contradicted by Aghajani, Hojjati, and Elmiyeh (2014) found that resistance training group has got better results in speed, agility, and explosive power than plyometric group; the findings are in line with Vissing et al. (2008).

In general, the results of the study showed that the students who performed 8 weeks of plyometric training registered better records in agility, speed, and explosive power compared with those participated in 8 weeks of resistance training. Also in the plyometric group maybe the increased speed of message transfer from muscle to the nerve center and vice versa led to better records in speed test compared with the resistance training group. Moreover, about explosive power, probably fast-twitch motor units are more called in plyometric exercises in comparison to resistance exercises. Based on this result, the researcher accepted hypothesis H1. 5 and rejected hypothesis H0.6 at 0.05 level of confidence.

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary

The purpose of this study was to compare the effects of comparison of plyometric and resistance training on speed, agility, and explosive power in the case of Gondar University regular sport science students. A variety of studies is being conducted on physical education and sports sciences in the world. Some studies investigate the effect of different training programs on physical abilities. These studies typically aim to examine what training programs may improve physical skills in athletes. Plyometric exercises hinge on a set of mechanical and physiological skills and abilities. Researchers have shown that plyometric training, when used with a periodized strength-training program, can contribute to improvements in vertical jump performance, acceleration, leg strength, muscular power, increased joint awareness, and overall proprioception. Resistance training also is known as strength or weight training has become one of the most popular forms of exercise both for enhancing an individual's physical fitness and for conditioning athletes. Participated in resistance training programs expect to gain certain benefits, such as increased strength, increased muscle size, improved sports performance, increased fat-free mass, and decreased body fat. Research results show that resistance training improves explosive power, vertical jump, and speed in professional soccer players by affecting the leg extensor muscles.

It is popular that, plyometric and resistance training improves the speed, agility, and explosive power of an athlete in different sport participation. But different scholars had been conducted different researches and different conclusions. Some said that plyometric training and resistance training improves speed, agility and power, and others also conclude that among physical fitness components, some fitness component didn't improve in relative to others. It is logical that Plyometric and resistance training cannot improve all fitness components equally and similarly. This is because; through its variability of training designees and each training program contain different types of workouts, volume, intensity, and ways of implementation. So it is unknown and did not clearly emphasize that to what extent plyometric and resistance training improves speed, agility, and explosive power. And among plyometric and resistance training, which one highly improved speed, agility, and power and recommended for performance improvement. Based on this, the researcher was investigated the comparison of the effect of plyometric and resistance training on speed, agility, and explosive power.

In order to conduct the study, there were basic objectives, such as:

1. To identify the effects of plyometric training on speed, agility, and explosive power.
2. To determine the effects of resistance training on speed, agility, and explosive power.
3. To compare the effects of plyometric and resistance training on speed, agility, and explosive power.
4. To determine among plyometric and resistance training, which one is the most important training to improve speed, agility and explosive power.

And also conducting this study has several significances. Among them:

- It will scrutinize the effects of plyometric and resistance training on speed, agility, and explosive power of students.
- It will determine that among the two training types, which type of training will recommended for the improvement of such physical quality (fitness variables) in the study.
- It will indicate the importance of different training types for athlete, coach, teacher and other concerning body.
- It will serve as the baseline to the other researcher for further study.

In accordance with the above specific objectives, some hypotheses were designed that are concurrent with the objective of study. These hypotheses were explained according to the result in the discussion part of the study. To conduct this study, 40 Male regular sport science students were selected through stratified and proportional simple random sampling technique. Among the samples, 13 subjects for plyometric training group, 13 subjects for resistance training group and 14 subjects also for the control group were assigned. The subject in each group was arranged through counterbalancing for the reliability of the study. In the study, quantitative data were collected through appropriate fitness tests such as flying 30 m sprint test (speed), agility t-test (agility), and vertical jump test (explosive power). And the recorded quantitative data were analyzed through inferential statistics such as paired sample t-test and independent sample t-test in SPSS version 23 software program.

The following findings of the study were conducted in t-test statistics.

- Based on the findings in the study, speed, agility, and explosive power of students were shown improvements as posttest compared to pretest measurements through 8 weeks plyometric training interventions.
- Based on the findings, the speed, agility, and explosive power of students were shown improvements as posttest recorded result compared to pretest results through 8 weeks of the resistance training intervention.
- But speed and explosive power of students in the control group were not shown improvements as posttest compared to pretest. Whereas, the agility level of students in the control group was shown improvement as a posttest compared to the pretest.
- Based on independent sample t-test result, students those performed 8-week plyometric training were registered better records in speed, agility and explosive power than those participated in resistance training

5.2 Conclusions

Based on the findings found in the study, the researcher has investigated the following conclusions.

- The intervention of eight weeks plyometric training significantly improves the speed, agility, and explosive power of students.
- Eight weeks resistance training significantly improves the speed, agility, and explosive power of students.
- Eight weeks plyometric training significantly improves speed, agility, and explosive power than resistance training.

5.3 Recommendations

Based on the results, discussions, and finding of the study, the researcher recommended the following points.

- ❖ As shown in the study, plyometric training improves the performance of the students than resistance training. So it's better to apply well planned and structured plyometric training for athlete development.
- ❖ When considering the practical application of PT and RT, coaches should consider many aspects of the training program. Elements of programming such as program length, frequency of sessions, the intensity of exercises, and volume are also crucial to the effects of training and may differ depending on the outcome measure. The development of fitness depends on such variables.
- ❖ The student should actively participate in each training program and fulfill sporting facilities. Because it has its own factor during training and fitness tests.
- ❖ It is better that, each fitness test should measure or record through well designed scientific instruments for the reliability of the test. The errors that omit the fraction of second in speed and agility test affect the study.
- ❖ And the researcher recommended that additional study should be conducted on other training types for the development of sport and performance enhancement. There are so

many research studies that have been conducted through “effects of plyometric and resistance training on fitness variables in Male athletes, students, and other respondents”. So the researcher recommended that it is better to conduct the effects of plyometric and resistance training on other several fitness variables in case of Female athletes, students and participants, and also further study should be conducted through the effects of combined plyometric and resistance training on several physical fitness components and skills of athlete.

- ❖ Additional study also important to identify the comparisons of the combination of plyometric and resistance training and each training group alone highly improved physical fitness components.

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APPENDICES

Appendix 1:

Plan for plyometric and resistance training

Basic tips that important for this plyometric and resistance training plan**.**

- In this training, the following key points are important.
- ✓ All training principles are applied, because this principle of training reduces the risk of injury and improve a performance of an individual.
- ✓ Before start given training, necessary wearing style is important. And well organized warming up and cooling down also used.
- ✓ In every training session, the loads of training will gradually increase through increasing intensity and volume of training and reducing the recovery time between set and repetition.
- ✓ Adequate recovery time is allotted.
- ✓ During weight based and resistance training, the load will maximize through increasing the mass of the load and use strong resistance band.
- ✓ The training will takes place 3 days per week.
- ✓ In this training plan, Plyometric and resistance training merely develop upper and lower body parts. But abdominals and back body muscles will develop slightly. So I will apply extra core stability training drills to improve this muscle group.

A. 8 Weeks training planning for plyometric experimental group

Weeks (from Dec 25- Feb 25 E.C)	Body parts	Types of work outs	Intensities	Sets	Repetition	Recovery b/n set	Recovery/Reps	Volume minute
Week 1	All body parts	-general conditioning,	Low	--	----	-----	------	40
		ABCS of training,		2	3	5	2-3	
Week 2	Lower	Vertical jump, leg hops, lounges, diagonal/lateral jump	Low	3	10-15	5-7	2-3	60
	Upper	Push up,	Moderate	3	3×25	5	2-3	60

		explosive push up, clapping push up,	Low	3	3	6		
Week 3	Lower	Vertical jump	Moderate	3	4×15 seconds	5	30 seconds	50
		obstacle jump, box shuffles,	Moderate	3	4	7	2-3	
	Upper	Clapping push up,	Low	3	3	6	2-3	60
		over hand throw,	Moderate	4	10	5	30 seconds	
		wall press	Moderate	3	4×30 seconds	7	3	
Week 4	Lower	tuck jump long jump,	Moderate	3	10	5-6	1-2	65
	Upper	chest throw, over hand throw,	Low	4	5 for each	7	2-3	
		push up,	Moderate	3	2×25	6	3	
Week 5	Lower	Squat, split squat, donkey kicks,	Moderate	2	5×30 seconds	7	3	70
		box jumps, drop jumps	Moderate	3	20-30	6	2-3	
	Upper	Medicine ball press,	Moderate	3	4	5	2	60
		2 hand overhead throw	Moderate	2	15-20	5	2-3	
Week 6	Lower	Hurdle jumps, 1 leg zigzag jump,	High	3	4	7	3	60
		2 leg box hoping,	High	3	3×7 hops	7	3	
	Upper	Jumping spider,	High	3	4	7	3	60-70
		Wall press,	Moderate	3	3×45 seconds	6	2-3	
		explosive pushup	High	3	3×25	8	3	
		push ups	Moderate	3	3×25	8	3-4	
Week 7	Lower	Lateral jumps, drop jump, long jump,	Moderate	3	5	7	4	50
		Box jumps, drop + vertical jump, 1 leg diagonal jumps	Moderate	3 each	3×5 each	6	3	

	Upper	Jumping spider,	High	3	4	7	3	70
		explosive push up,	High	2	3	8	3-4	
		overarm throw	Moderate	3	4×15	5	2	
		1 leg zigzag jump, tuck jumps,	High	2	4	6	2-3	
Week 8	Lower	1 leg box hoping,	Moderate	2	4×5 hops	6	3-4	80
		Hop step jump, obstacle jumps, box shuffles,	High	2/each	3×7 jump each	6	3	
	Upper	Wall press	Moderate	3	2×10 sec	5	2-3	
		clapping push up,	Moderate	3	3×10	8	4	
		explosive push up,	High	2	3×15	6	4	

The plyometric program should use the principles of progression and overload. This can be accomplished by manipulating the volume dosage (reps, sets, weight, etc.) of many different variables. The quality of the work is more important with plyometric than the quantity of the work. In order to recruit the fast-twitch fibers, the intensity of the work should be performed at high levels of intensity 80-100% maximum volitional contraction (MVC). Additionally, the rate of the muscle stretch is more important than the length of the stretch. During the training session, if the quality of the movement performance deteriorates and is not able to be performed correctly, then the athlete is probably experiencing fatigue and the plyometric portion of the exercise session should be terminated. Based on the rest, recovery, and reparative phase following high intensity resistive plyometric exercises, there should be increased recovery time when compared to other types of exercise. Although no evidence exists regarding the optimum rest period between high-intensity plyometric workouts, the authors recommend 48-72 hours between sessions (Wathen, 1993).

B. 8 Weeks training Planning for resistance experimental groups

Weeks (from Dec 25- Feb 25 E.C)	Body parts	Work outs	Set	Repetition	Recovery/set	Recovery/reps (minute)	Volume in minute	Remark
Week 1	All body parts	General conditioning	----	-----	----	------	60	Regular warming up and cooling down are necessary
		ABCS drills,	3	4 each drill	4-6	1-2		
Week 2	Lower	Front squat, bent over row	3	3×30 seconds	10	5	65	Use resistance band for lower body training
	Upper	Chest press, back & side pull,	3	5×45 seconds	8	4		
Week 3	Lower	Leg split,	3	2×10 each leg	8	4-5	70	Use resistance band
		Donkey kicks, lateral leg lift, leg split	2	3×20 for each	7	4		
	Upper	Standing bicep curl,	3	3×20 seconds	8	5		
		push up	2	3×25	7	4		
Week 4	Lower	Lateral leg lift,	2	2×15 each leg	8	3-4	70	Use resistance band & medicine ball
		donkey kicks	2	2×20 each leg	8	3-4		
	Abdominals	Banded bridge, banded toe taps	2	3	5	2		
	Upper	Push up(medicine ball),	3	4×25	5-7	2-3		
		Wall push, wall press	3	3×30 seconds	8	5		
Week 5	Lower	High knee, leg extension, leg curl	2	3	7	4		

	Upper	Push up + shoulder press	3	2	8	3-4	80	Use resistance band
Week 6	Lower	Split squat, Resisted bridge	3	15 each side	6	3	80	Resistance band mandatory
		Front squat. resisted bridge, leg lift	2	4	6	3		
	Abdominals	Banded lower & lift, pelvic push	3	3	6	2		
	Upper	Banded open & close, back pull, side pull	3	4×10	8	5		
Week 7	Lower	Side lounge, bench glute bridge	3	15-20	7	3-4	70	With resistance band
	Upper	Triceps extension, back pull	2	20	7	5		
Week 8	Lower	Lounge, squat(jump)	3	4×60 seconds	8	3-5	75	Use dumbbell & resistance band
		Side bridge, leg abduction	3	3×10 each sides	6-8	3-4		
	Abdominals	Banded bridge, banded toe taps	2	3	6	3		
	Upper	Bicep curl, shoulder press arm raise	3	25-30	6	3-4		

Note: the volume during training in the above table indicates the duration of training in each session.

- ✓ The American College of Sports Medicine recommends that resistance training should be progressive in nature (for example, follow the principle of progressive overload), individualized, and provide a stimulus to all the major muscle groups (chest, back, shoulders, arms, abdominals, and legs). They recommend that beginners do one set of eight to 10 exercises for the major muscle groups, eight to 12 repetitions (reps) to fatigue, two to three days per week (multiple-set regimens may provide greater benefits if time allows).

Appendix 2:

Profile of participants

Plyometric experimental group

No	Age	Height	Weight	BMI	Class year (university level)
1	23	1.68	62	21.967	2
2	21	1.71	67	22.914	3
3	23	1.74	65	21.469	3
4	23	1.70	66	22.837	3
5	20	1.62	56	21.338	2
6	23	1.72	67	22.647	3
7	20	1.66	57	20.685	2
8	20	1.64	62	23.052	3
9	21	1.67	63	22.589	3
10	23	1.69	61	21.359	2
11	21	1.68	57	20.196	3
12	23	1.65	61	22.406	3
13	22	1.71	64	21.887	2

Resistance experimental group

No	Age	Height	Weight	BMI	Class year (university level)
1	23	1.77	64	20.428	2
2	22	1.65	61	22.406	2
3	23	1.63	65	24.465	3
4	22	1.60	58	22.656	3
5	19	1.61	58	22.356	2
6	21	1.64	57	21.193	3
7	20	1.67	62	22.231	3
8	24	1.71	69	23.597	3
9	22	1.68	65	23.04	3
10	24	1.76	69	22.275	3
11	23	1.74	66	21.799	2
12	22	165	58	21.304	3
13	22	1.63	59	22.206	3

Control group

No	Age	Height	Weight	BMI	Class year (university level)
1	21	1.64	59	21.936	3
2	20	1.62	57	21.719	3
3	23	1.67	61	21.872	2
4	22	1.74	66	22.129	3
5	21	1.69	64	22.408	3
6	24	1.74	67	22.647	3
7	21	1.58	57	22.833	2
8	20	1.65	58	21.304	3
9	22	1.64	61	22.680	2
10	22	1.68	66	23.384	3
11	21	1.60	57	22.266	3
12	23	1.75	63	20.571	2
13	24	1.72	67	22.647	3
14	23	174	65	21.469	3

Appendix 3:

Pre & post fitness test measurement for participants

The pre and post test result of the plyometric training experimental group

No	Speed test (sec)		Agility test (sec)		Explosive power test (cm)	
	Pre	Post	Pre	Post	Pre	Post
1	4.06	3.31	11.685	10.59	43	48
2	4.10	3.105	11.62	10.43	42.9	46.8
3	4.20	3.23	11.585	10.55	45	48.3
4	4.205	3.135	11.645	9.865	41.6	48
5	4.115	3.10	11.785	9.985	39	45.7
6	3.79	3.015	11.145	10.16	44	49.3
7	4.08	3.05	11.245	10.165	43	46.5
8	3.99	3.10	11.20	10.175	40	45
9	3.74	3.04	11.38	10.12	39.5	46
10	3.885	3.075	11.735	9.88	43	49.3
11	3.915	3.05	11.325	10.27	41.8	46.7
12	4.055	3.16	11.075	10.15	42	44
13	4.275	3.67	11.365	10.64	43.4	48.6

The pre and post test result of the resistance training experimental group

No	Speed test (sec)		Agility test (sec)		Explosive power test (cm)	
	Pre	Post	Pre	Post	Pre	Post
1	4.245	3.615	11.37	11.02	42.6	47
2	4.095	3.91	11.105	10.505	41	46.3
3	4.03	3.70	11.38	10.55	43	46.8
4	4.285	3.715	10.855	10.12	45	48
5	4.22	3.78	11.71	11.09	40	44.7
6	4.52	3.875	11.355	10.605	40.9	43
7	4.085	3.32	11.515	10.695	42.3	47
8	4.045	3.35	11.045	10.46	41	45.5
9	4.185	3.485	11.165	10.365	38	43.7
10	4.435	3.62	11.20	10.42	43	45.8
11	3.08	2.59	11.14	10.19	40	46.4
12	4.14	3.695	11.105	10.365	45	48.3
13	4.63	3.88	11.63	10.89	42.9	46

The pre and post test result of the control group

No	Speed test (sec)		Agility test (sec)		Explosive power test (cm)	
	Pre	Post	pre	Post	Pre	Post
1	3.605	3.515	11.195	11.15	46	45.8
2	3.33	3.20	12.395	12.37	44	44.3
3	3.615	3.385	10.825	10.655	41	42
4	3.575	3.45	12.89	12.795	45	45.4
5	3.795	3.395	10.17	10.08	40.8	40
6	4.22	4.035	11.705	11.535	41	41.3
7	3.905	3.89	12.015	11.765	45	46
8	4.215	4.27	10.985	10.585	43	42.5
9	3.86	4.115	11.295	11.15	39.7	40
10	4.025	3.725	11.06	11.13	41.7	42
11	4.12	4.12	11.14	11.10	44	44.8
12	4.15	4.06	11.19	10.685	40	39.5
13	4.32	4.36	11.245	11.38	38	39
14	4.495	4.56	11.235	10.705	39.6	40

Appendix 4:

Participants picture during fitness test (flying 30 m speed test)

Appendix 5:

Photographs of students during agility test (agility T-test)