CHAPTER ONE

INTRODUCTION

Background to the Study

Sport is one of the extra-curricular activities in the universities that offer the students the opportunity of being well-rounded and to succeed in the world around them. Its health benefits especially in the prevention of several chronic diseases such as cardiovascular diseases, diabetes, cancer and obesity cannot be over emphasised. Sport is divided into two main categories namely: outdoor and indoor activities. Outdoor activities may include: football, volleyball, basketball, hockey, cricket, tennis, swimming, track and field events, while badminton, chess, scrabble, table tennis and martial arts are among the indoor sports. However, each of these sports requires specific skills, techniques and movements that could be mastered through training.

Any student that participates or competes in any of these sports in the university should be a student- athlete aged between 12 and 25 years. During this period, a student-athlete is full of life and exuberance. It is expedient that these athletes need to undergo a planned sports conditioning programme that would give them a sense of purpose to face challenges that may affect their academic work and sports achievement. Training therefore is very vital for the effective life of these athletes. This training will equip them with a sound base knowledge, values, techniques and skills in preparation for professional competitions such as Nigerian University Games Association (NUGA) while it concomitantly promotes good healthy lifestyle to face their academic work.

Training in sports may include; strength, interval, aerobic, anaerobic, endurance, circuit and a few others that can be used to obtain the required improvement in fitness. In basketball training, for example, athletes focus on building up strength and power; football athletes train on speed and agility while track and field athletes focus on strength, speed and agility training. It therefore means that strength training is an important part of an overall fitness programme. Strength training can be carried out isotonically, isokinetically, isometrically and plyometrically (Bhavna & Sarika, 2010). Plyometric training seems to be the best method to increase muscular strength for it bridges the gap between power and speed (Kraemer & Newton, 1994). Power is the product of strength and speed, but an increase in strength or speed will increase power. The American College of Sports Medicine (1999) suggested that in order to maximise power output or speed of movement, the first phase of training should focus on increasing maximum strength for building a strong foundation and the second phase is devoted to power and speed training. Numerous studies have also reported that plyometrics can improve power, explosiveness (speed and strength), sprint and agility to compete at athlete's peak abilities in most popular sports (Beardsley, 2014; Chelly, 2014; Kraemer & Newton, 1994; MacDonald, 2013; Thomas, French & Hayes, 2009).

The term plyometric may sound unfamiliar, but most sports enthusiasts have at one time or the other taken part in plyometric training. It is a form of specialised strength training that uses fast muscular contractions to improve power and speed in the sports conditioning programme by coaches and athletes. "Plyometric" is defined as a quick, powerful movement involving an eccentric muscular contraction, followed by a concentric, rapid contraction of the same muscles for the purpose of developing a forceful movement over a short period of time (MacDonald, 2013). Plyometric training originated in the late 1960's from Soviet Union and was developed by Russian exercise scientist and coach, Yuri Verkhoshansky (Beardsley, 2014). Verkhoshanky wanted to discover ways to develop the jumping ability of his Olympic athletes. He made experiment with many jumps, different exercises but the depth jump appeared to be the best for duplicating the forces in the landing and takeoff.

Thus, Verkhoshansky used depth jumps focusing on reducing the ground contact times, switching from eccentric to concentric action more quickly to increase the speed and explosiveness of his athletes. The landing and takeoff were executed in an extremely short period of time. This training process at that time was called “shock method” (Patalas, 2013). The term “plyometric” was later coined by an American athlete Fred Wilt, who after watching the Soviets dominate the Olympics during the 60-70’s, decided to investigate how they were training (MacDonald, 2013). As the Soviets began to produce superior athletes in various sports including track and field, gymnastics and power lifting, interest regarding this training increased. Since then other sports across the globe started incorporating plyometrics into their sports training programmes to help their athletes become faster, and exhibit more explosive power.

According to The American College of Sports Medicine (2009), plyometric training is defined as a quick, powerful movement involving an eccentric contraction, followed immediately by an explosive concentric contraction. Plyometric training involves a rapid stretching of muscle (eccentric phase) immediately followed by a concentric or shortening action of the same muscle and connective tissue. This rapid combination of eccentric and concentric action by muscle is called stretch-shortening cycle. As a muscle stretches and contracts eccentrically, it lengthens while it contracts to produce storable energy (Abbas, 2005).The stored elastic energy within the muscle is used to produce more force than can be provided by using only concentric contraction alone (ACSM, 2009). Plyometric training bridges the gap between speed and strength. The two main categories of plyometric are lower and upper body plyometric training (Quinn, 2013). Lower body plyometric training includes jumps, hops, bounds and lunges, while the upper body plyometric training requires the use of a medicine ball throws and plyometric push-ups (Walker, 2014). Its health benefits include improved measures of muscular strength and power (Quinn, 2013), reduced incidence of serious knee injuries (Elite Athletic Performance, 2013), and running economy (Bhavna & Sarika, 2010).

Several studies have shown that when combined with resistance and anaerobic training, plyometric training can improve strength, vertical jump and speed (Beardsley, 2014; Coach Colleague, 2009; Matz, 2013; Quinn, 2013). Plyometric and weight training can enhance strength performance (Harrison & Gaffney, 2000; Hennessy & Kilty, 2001). Rimmer and Sleivert (2000) narrated that a plyometric intervention programme resulted in an improvement in sprint and decrease in ground contact time. Plyometric training can be used often by athletes who need to generate quick burst of maximal effort, movement required in most popular sports such as football, basketball, track and field, racket games, rugby and martial arts in a short amount of time (Comyns, 2012; Idea Health Fitness, 2009; Quinn, 2013).

The cardiovascular health is currently a global issue to all and sundry. Cardiovascular relates to the circulatory system, which comprises the heart and blood vessels that carry nutrients and oxygen to the tissues of the body and remove carbon dioxide and other wastes from the body (Medicine Net, 2015).Therefore athletes' cardiovascular responses to training cannot be ignored. Training places an increased demand on the cardiovascular system. The cardiovascular variables fluctuate on beat to beat basis during any physical activity depending on the type of training. The variables may include the following: Heart Rate (HR), Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), Mean Arterial Pressure (MAP), Rate Pressure Product (RPP) and to mention but a few.

Electrocardiogram is a simple, painless and noninvasive medical test that measures the electrical activity of the heart as it contracts. It helps to understand how the heart works. The Electrocardiogram (ECG) can help diagnose a range of conditions including heart arrhythmias, heart enlargement, heart inflammation and coronary heart disease. As the heart contracts, it produces these three waves namely are P wave, QRS complex and T wave. Any irregularity in the heart rhythm or damage to the heart muscle can change the electrical activity of the heart so that the shape of the ECG is changed and may lead to sudden death. Plyometric training may demonstrate strong influences on cardiovascular health in student-athletes which are capable of antagonising the sympathetic effects on the heart and blood vessels. Independently, the decrease in blood pressure (BP), heart rate (HR), mean arterial pressure (MAP) and rate pressure product (RPP) reduces the risk of cardiovascular diseases such as arterial hypertension.

Despite the numerous studies on plyometric training, only a few studies (Arazi, Abbas, Seyed, & Seyed, 2014) compared the effect of post-plyometric exercise hypotension and heart rate in normotensive individuals, and they found out that after an acute exercise bout, blood pressure (BP) levels are reduced for minutes or hours in relation to post-exercise levels. This phenomenon is called post-plyometric exercise hypertension and has been highly recommended for the treatment and prevention of arterial hypertension. Additionally, Moro, Ewan, and Gerardo (2013) investigated the blood pressure and heart rate responses to two resistance training techniques of different intensity in obese individuals, the subjects showed the same cardiovascular response to different intensity. Only Bhavna and Sarika (2010) have directly conducted a study on the effects of concentric vs eccentric loading on cardiovascular variables and ECG in Amritsar but without using athletes. More so, the health and fitness requirements of athletes are different from other general population. Furthermore, these studies were not carried out in Nigeria.

Although plyometric training has been a useful training technique for developing optimal sports performance in most popular sports, yet it is relatively unknown whether plyometric training influences the cardiovascular health especially the ECG which is capable of affecting the heart and blood vessels of young university athletes. Therefore, more information is necessary, since it has not been established.

Statement of the Problem

With reference to sudden, unexpected death of the Late Super Eagles midfielder Samuel Okwaraji at the field of play on 12th August years back at National Stadium Lagos, it was unparalleled, worrisome and focuses new attention on the athletes cardiovascular health condition in sports by all. It occurred suddenly without warning or signs at the field of play. More so, it can occur to any individual including coaches or athletes irrespective of age or sex in any setting therefore, should not be ignored. Anybody can fall a victim. Although there may be other causes of such unexpected deaths, but this study focuses on effect of training on young university athletes cardiovascular health.

Training places an increased demand on the cardiovascular system. The cardiovascular variables fluctuate on beat to beat basis during any physical activity depending on the type of training. During intense aerobic exercise, the oxygen consumption of muscle tissue increases markedly and cardiac output must rise to meet the demands. Over time, aerobic training results in increased heart rate during exercise, increased ventricular stroke volume and increased cardiac output among other effects. Plyometric training has been a useful training technique for optimising performance in most popular sports by coaches and athletes in the preparation for professional competitions. It helps athletes to become faster, exhibit more explosive power and agility to compete in most sports. However, it is possible that different plyometric training workload may have different effects on cardiovascular health.

Only a few studies known to the researcher have directly investigated the cardiovascular responses following plyometric training but without including the athletes and ECG. These few studies that investigated the cardiovascular responses to plyometric training have focused on the elderly, obese and patients with different aliments. More so, athletes have different health and fitness requirements from other general population in any sport conditioning programme. The study by Lobo (2012) on cardiovascular responses to plyometric focused on elderly; Moro, et al. (2013) used the obese individuals, while Ankur and Maulik (2013) used the patients with different aliments without including ECG.

Although plyometric training has been a useful training technique for developing optimal sports performance in most sports, yet it is relatively unknown whether plyometric affect the cardiovascular health and ECG of university athletes. To the limited knowledge of the researcher, there were no studies that have investigated the effect of ECG response of athletes following plyometric training in the literature. There is need therefore for this study, so as probably to close this existing gap and provide a baseline data for future research.

Purpose of the Study

The purpose of this study is to determine the effect of lower and upper body plyometric training on cardiovascular variables and ECG of university athletes.

Specifically the study intends to find out:

1. the heart rate of university athletes using lower body plyometric training and those in the control group.
2. the systolic blood pressure (SBP) of university athletes using lower body plyometric training and those in the control group.
3. the diastolic blood pressure (DBP) of university athletes using lower body plyometric training and those in the control group.
4. the mean arterial pressure (MAP) of university athletes using lower body plyometric training and those in the control group.
5. the rate pressure product (RPP) of university athletes using lower body plyometric training and those in the control group.

6. the P wave ECG readings of university athletes using lower body plyometric training and those in the control group.
7. The QRS complex ECG readings of university athletes using lower body plyometric training and those in the control group.
8. the T wave ECG readings of university athletes using lower body plyometric training and those in the control group.
9. the heart rate (HR) of university athletes using upper body plyometric training and those in the control group.
10. the systolic blood pressure (SBP) of university athletes using upper body plyometric training and those in the control group
11. the diastolic blood pressure (DBP) of university athletes using upper body plyometric training and those in the control group.
12. the mean arterial pressure (MAP) of university athletes using upper body plyometric training and those in the control group.
13. the rate pressure product (RPP) of university athletes using upper body plyometric training and those in the control group.
14. the P wave ECG readings of university athletes using upper body plyometric training and those in the control group.
15. the QRS complex ECG readings of university athletes using upper body plyometric training and those in the control group.
16. the T wave ECG readings of university athletes using upper body plyometric training and those in the control group.

Significance of the Study

The findings of this study may be beneficial to coaches and athletes because it would make them strive to avoid exercises such as backpacking and walking up a hill at a brisk pace which could be very dangerous to the functioning of the heart and may lead to heart attack or sudden cardiac death.

The findings of the study could also be useful to coaches who could use them to understand the implications of cardiovascular responses to training and could improve the coach's discipline on the need to conduct pre-exercise screening test before commencing any sports training to avoid athletes slumping to death on their training pitches.

The finding of this study could also guide the exercise scientists and coaches in prescribing exercises that may be of help to people with high blood pressure, stroke, and diabetes to enable them live a longer and healthier life.

The physical and health education specialists, physiotherapists, lecturers, sports officers, students, curriculum planners may benefit from the findings of this study as they may use the results as reference point to support both curriculum innovations and modifications on the existing physical education (PE) curriculum.

The results of this study could guide the sports institutions and relevant agencies to provide necessary sports facilities and equipment in schools and universities such as Electrocardiogram (ECG), automatic external defibrillators and other cardio emergency equipment to the coaches at the training venues to handle athletes with cardio abnormalities before commencing training. Also this may become a motivating factor for athletes as their health are considered first before sports performance.

The findings of the study could assist in future research by those who may want to replicate the work elsewhere and make further contributions to knowledge in this area as well as serve as a reference point.

Scope of the Study

The study was delimited to10 weeks lower and upper body plyometric training on cardiovascular variables and ECG. It was also delimited to male athletes of Nnamdi Azikiwe University, Awka. The study was delimited to the use of lower body plyometric training (ankle hops, squat jumps and tuck jumps), and upper body plyometric training (plyometric push-ups, medicine ball-chest throws and side throws) with low to moderate intensity. The study focused specifically on cardiovascular variables namely: HR, SBP, DBP, MAP and RPP and ECG parameters which are P wave, QRS complex and T wave irrespective of other cardiovascular and ECG variables. The mean, standard deviation and ANCOVA were the statistics used in the study.

Research Questions

The following research questions guided the study.

1. What is the mean heart rate (HR) of university athletes who were trained using lower body plyometric training and those in the control group?
2. What is the mean systolic blood pressure (SBP) of male university athletes who were trained using lower body plyometric training and those in the control group?
3. What is the mean diastolic blood pressure (DBP) of university athletes who were trained using lower body plyometric training and those in the control group?
4. What is the mean MAP of university athletes who were trained using lower body plyometric training and those in the control group?
5. What is the mean rate pressure product (RPP) of university athletes who were trained using lower body plyometric training and those in the control group?

6. What is the mean P wave on ECG readings of university athletes who were trained using lower body plyometric training and those in the control group?
7. What is the mean QRS complex on the ECG readings of university athletes who were trained using lower body plyometric training and those in the control group?
8. What is the mean T wave on the ECG readings of university athletes who were trained using lower body plyometric training and those in the control group?
9. What is the mean heart rate (HR) of university athletes who were trained using upper body plyometric training and those in the control group?
10. What is the mean systolic blood pressure (SBP) of university athletes who were trained using upper body plyometric training and those in the control group?
11. What is the mean diastolic blood pressure (DBP) of university athletes who were trained using upper body plyometric training and those in the control group?
12. What is the mean (MAP) of university athletes who were trained using upper body plyometric training and those in the control group?
13. What is the mean rate pressure product (RPP) of university athletes who were trained using upper body plyometric training and those in the control group?
14. What is the mean P wave on ECG readings of university athletes who were trained using upper body plyometric training and those in the control group?
15. What is the mean QRS complex on ECG readings of university athletes who were trained using upper body plyometric training and those in the control group?
16. What is the mean T wave on ECG readings of university athletes who were trained using upper body plyometric training and those in the control group?

Hypotheses

The following null hypotheses were tested at 0.05 level of significance.

1. There is no significant difference in the heart rate (HR) of university athletes who were trained using lower and upper body plyometric training and those in the control group.
2. There is no significant difference in the systolic blood pressure (SBP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.
3. There is no significant difference in the diastolic blood pressure (DBP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.
4. There is no significant difference in the mean arterial pressure (MAP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.
5. There is no significant difference in the rate pressure product (RPP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.
6. There is no significant difference in the P wave on ECG readings of university athletes who were trained using lower and upper body plyometric training and those in the control group.
7. There is no significant difference in the QRS complex on ECG readings of university athletes who were trained using lower and upper body plyometric training and those in the control group.
8. There is no significant difference in the T wave on ECG readings of university athletes who were trained using lower and upper body plyometric training and those in the control group.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

This chapter reviewed the literature related to the study. The review of related literature was carried out under the following sub-headings:

Conceptual Framework

Plyometric

Cardiovascular Variables

Electrocardiogram (ECG)

Theoretical Framework

Mechanical Model

Neurophysiological Model

Central Command Theory

Muscle Factor Model

Theoretical Studies

Empirical Studies

Plyometric and improvement of power output

Effects of Plyometric/Strength training on cardiovascular variables

Summary of Reviewed Literature

Conceptual Framework

Plyometric

The concept plyometric has a complex definition. Many authors have tried to define it based on how it works. WebMD (2014) and Kravit (2011) defined Plyometric as “jump training” or “shock method” originally developed by a Russian coach to improve the jumping abilities of his Olympic athletes, but it has become a popular workout routine for people of all ages, including children and adolescents. Walker (2014) referred to plyometric as highly effective form of power training designed to significantly improve sports performance. It manipulates the elasticity and strength of muscles by increasing the speed and force of their contractions.

Ratini (2013) defined plyometric as a training technique designed to increase muscular power and explosiveness. Ken (2013) added that plyometric training can act as the bridge between strength, power and speed. According to Ken, the goal of plyometric training is to develop the power and speed that are specific to a sport. Hitchcock (2013) was of the view that plyometrics are activities that enable a muscle to reach maximal force in the shortest amount of time with the goal of increasing both speed and power. Essentially, plyometric exercises enhance the series of elastic component and the stretch reflex by using movements similar to those used in the athlete's sport (Ken, 2013; Garlock, 2013). Garlock agreed that athletes, regardless of the sport they participate in, will benefit from plyometric training since it increases the amount of power an athlete produces during any sport performance. Plyometric training therefore is an essential component to any athlete's training programme.

According to Quinn (2013), plyometric exercises are specialised and high intensity training technique used to develop athletic power (strength and speed) and involves high intensity, explosive muscular contractions that invoke the stretch reflex (stretching the muscles before it contracts so that it contracts with greater force). Hill (1970) on definition of plyometrics added that muscles are loaded with a lengthening (eccentric) action, followed immediately by a shortening (concentric) action to reach their optimum force in the fastest time possible. Garlock asserted that plyometric training can be utilised to increase explosiveness, vertical jumping, and horizontal jumping, speed and body awareness.

Sankarmani, Sheriff, Rajeev and Alagesan (2012) also affirmed that plyometric is a quick powerful movement involving pre-stretching or countermovement that activates the stretch-shortening cycle. Within this powerful movement is an eccentric or force reduction phase; amortisation phase, or transition moment involving dynamic stabilisation and a concentric phase or force production phase. According to The American College of Sports Medicine (2009), plyometric is an exercise in which an eccentric muscle contraction is quickly followed by a concentric muscle contraction. In other words, when a muscle is rapidly contracted and lengthened, and then immediately followed with a further contraction and shortening, it is a plyometric exercise.

Art of Manliness (2010) defined plyometric as a type of activity or exercise in which an individual creates the most amount of muscular force the person can in a short period of time. The authors further explained that unlike typical strength training that involve long, slow movements designed to increase strength and mass, plyometric involves explosive movements designed to increase explosive speed and power. These types of exercises use the natural elasticity of muscles as well as their reflex capabilities to create quick, explosive power. Plyometric programmes have been beneficial and will continue to play a large part in training of athletes due to their tremendous applications to sport.

Twist (2008) in his study viewed plyometric as a type of movement involving the legs, core or upper extremities and uses a quick eccentric-concentric phase to harness elastic muscles properties while using neural drive to increase the number of active motor units thereby producing explosive power and acceleration. It involves preloading of the muscle using an eccentric (muscle lengthening) or negative, contraction prior to the concentric (muscle shortening) or positive, contraction phase. Baechle and Earle (2000) and Chu (1999) saw plyometric as an exercise that enables a muscle to reach maximum force in the shortest possible time. The muscle is loaded with an eccentric (lengthening) action, followed immediately by a concentric (shortening) action.

However, for this study, plyometric is a form of specialised strength training that uses fast muscular contractions to improve power and speed in most popular sports conditioning by the coaches and athletes.

Cardiovascular Variables

The word cardio means heart, while vascular refers to blood vessels. Cardiovascular is therefore relating to the circulatory system, which comprises the heart and blood vessels that carries nutrients and oxygen to the tissues of the body and removes carbon dioxide and other wastes from the body (Medicine Net, 2015).

The following are the cardiovascular variables which fluctuate on a beat to beat basis which may include the following: heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, rate pressure product.

Waehner (2014) saw heart rate (HR) as the number of heartbeats per unit of time, usually per minute. The pulse is often taken at the wrist to estimate the heart rate. The heart rate is based on the number of contractions of the ventricles (the lower chamber of the heart).The heart rate may be too fast (tachycardiac) or too slow (bradycardiac). The normal resting adult human heart rate ranges from 60-100 bpm. When the heart is not beating in a regular pattern, this is referred to as an arrhythmia. These abnormalities of heart rate sometimes indicate disease. Steinbaum (2014) stated that systolic blood pressure (SBP) is when your heart beats; it contracts and pushes blood through the arteries to the rest of the body. This force creates pressure on the artery; this is called systolic blood pressure. The American Heart Association (2011) explained that a normal systolic blood pressure is below 120. A systolic blood pressure of 120 to 139 means the person has pre-hypertension or borderline high blood pressure. Even people with pre-hypertension are at a higher risk of developing heart disease. A systolic blood pressure of 140mmHg or higher is considered to be hypertension, or high blood pressure.

According to Medicine Net (2015), diastolic pressure (DBP) is the specifically the minimum arterial pressure during relaxation and dilatation of the ventricles of the heart when the ventricles fill with blood. In a blood pressure reading, the diastolic pressure is typically the second number recorded. For example, with a blood pressure of 120/80 (120 over 80), the diastolic pressure is 80. By "80" is meant 80 mmHg (millimeters of mercury).

According to American Heart Association (2014), narrated that mean arterial pressure (MAP) is a term used in medicine to describe an average blood pressure in an individual. As blood is pumped out of the left ventricle into the arteries, pressure is generated. MAP gives one an indication of the mean (average) perfusion pressure across the entire cardiac cycle. MAP is normally between 70-110 mmHg. It is belief that a MAP that is greater than 60 mmHg is enough to sustain the organs of the average person. To calculate a mean arterial pressure, double the diastolic blood pressure and add the sum to the systolic blood pressure, then divide by 3 (Klabunde, 2007).

Moro, et al. (2013) expressed that rate pressure product, is also known as cardiovascular product or double product, and is used in cardiology and exercise physiology to determine the myocardial workload. Rate Pressure Product (RPP) = Heart Rate (HR) x Systolic Blood Pressure (SBP) with the units for the heart rate being beats per minute and for the blood pressure mmHg. Rate pressure product is a measure of the stress put on the cardiac muscle based on the number of times it needs to beat per minute and arterial blood pressure that it is pumping against (SBP). It will be a direct indication of the energy demand of the heart and thus a good measure of the energy consumption of the heart. Rate pressure product allows you to calculate the internal workload or hemodynamic response. Heart rate and systolic blood pressure rises with activity making them reproducible with exercise, so it is relatively easy to predict their levels of efficiency.

Electrocardiogram (ECG)

An ECG or EKG is an abbreviation for Electrocardiogram and it is a simple, painless and noninvasive medical test that measures the electrical activity of the heart beat (AHA, 2015). It helps to understand how the heart works. With each heartbeat, an electrical impulse (wave) travels from the top of the heart to the bottom. This wave causes the muscle to squeeze and pump blood from the heart. A normal heart beat on ECG will show the timing on the top and lower chambers. The right and left atria or upper chambers make the first wave called a "P wave" – following a flat line when the electrical impulse goes to the bottom chambers. The right and left bottom chambers or ventricles make the next wave called a "QRS complex". The final wave or "T wave" represents electrical recovery or return to a resting state for the ventricles.

According to The Victoria State Government (2015), an electrocardiogram is a medical test that detects cardiac (heart) abnormalities by measuring the electrical activity generated by the heart as it contracts. The ECG can help diagnose a range of conditions including heart arrhythmias, heart enlargement, heart inflammation (pericarditis or myocarditis) and coronary heart disease. ECGs from normal, healthy hearts have a characteristic shape. Any irregularity in the heart rhythm or damage to the heart muscle can change the electrical activity of the heart so that the shape of the ECG is changed.

Theoretical Framework

The most commonly used theories that explain the physiology of plyometric according to reviewed literature are mechanical and neurophysiological models, while central command theory and muscle factor models explained the responses of the cardiovascular system to exercise.

Mechanical Model

The quantum mechanics model was established during the first half of the 20thcentury and was propounded by Max Planck, Niels Bohr, Werner Heisenberg, Louis de Broglie, Arthur Compton, Albert Einstein, Erwin Schrodinger, Max Born, John von Neumann, Paul Dirac, Enrico Fermi, and Wolfgang Pauli, MaxVou Laue, Freeman Dyson, and David Hilbert (Dummies, 2014).The quantum mechanics was based on the quantum theory. It was based on the idea that matter also has properties associated with waves. According to quantum theory, it is impossible to know the exact position and momentum of an electron at the same time. This was known as the **uncertainty principle**. Quizlet (2014) added that the quantum mechanical model of the atom uses complex shapes of orbital (sometimes called electron clouds), volumes of space in which there was likely to be an electron. So, this model was based on probability rather than certainty.

In this model, the elastic energy was created in the muscles and tendons are stored as a result of a rapid stretch. This stored energy is then released when the stretch is followed immediately by a concentric muscle action. According to Hill (1970), the effect is like that of stretching a spring, which wants to return to its natural length. The spring in this case is a component of the muscles and tendons called the series elastic component. When a stretch is applied to the muscle tendons, then rapidly released during a muscle contraction, an increase of muscular force production occurs. This increase in force production is contributed to the muscles and tendons elastic response to return to their natural length prior to the stretch (Asmussen & Bonde-Petersen, 1974). The mechanical model is similar to a rubber band; it creates tension or stored energy, which is utilised to create a rapid contraction so it may return to the original length (Kravitz & Fowler, 2011).

Mackenzie (2000) explained that mechanical model is like taking rubber band and stretching it out; which will cause the band to develop “potential energy”. If you suddenly release a stretched rubber band, the potential energy would then release very rapidly. Similar type principles can be applied to the human body. Muscles, tendons and ligaments all contain elastic properties that can be utilised in powerful, explosive, athletic actions. Furthermore, he narrated that the main powerhouse or driving force behind plyometric movement is known as the "series elastic component" (SEC). The SEC is partly composed of muscular elasticity, but is mainly driven by the elastic components in the tendons. Although the SEC is very similar to stretching a rubber band, but there are some differences as well. During the "loading" or eccentric phase of a plyometric action (muscle lengthening), there is potential elastic energy stored in the tendons and muscles. If there is a quick transition to the concentric or "explosive" phase, then the elastic, potential energy stored in the tendons can be utilised in the explosive action.

Moreover, Lindsey (2014) added that if, the eccentric phase takes too long, or the transition to the concentric phase is not fast enough, much of the stored elastic potential energy ends up dissipating as heat. This is where the plyometric action is different from a rubber band. As long as the rubber band is not stretched too far, the stored energy will remain there until released. This is not the case with stored elastic energy in the muscles/tendons however, as the muscles will simply just "release" and stretch their fibers instead.

The mechanical model is applied to human body and it is also applied in this study because it is similar to taking a rubber band or spring and stretches it out; the stored energy is released when the stretch is followed immediately by a concentric action. The effect of plyometric training is like that of stretching a spring. The spring in this case is a component of the muscles tendons and ligaments that can be utilised in powerful, explosive and athletic performance. Although the series elastic component is very similar to stretching a rubber band which is vital in this study, but there should be a quick transition to the concentric phase in order to release the stored energy

Neurophysiological Model

Neurophysiological model was founded by Dr. Jastreboff in 1979 (Garlock, 2013). It was called Neurophysiological model of Tinnitus. This model simplified the way to view how our brain filters and categorizes sounds on day to day basis. It explained that the brain has a major role to play in controlling the nervous system- involuntary action. Neurophysiological model is one of the models that explain how plyometric exercise correlate with the production of power. The neurophysiological model of plyometric exercise is also known as the stretch reflex. When a muscle lengthens, the muscle spindle is stretched and its nerve activity increases. This increases alpha motor neuron activity, causing the muscle fibers to contract and thus resist the stretching.

Hitchcock (2013) narrated that a neurophysiological model is also known as the stretch reflex. This involves change in force-velocity of a muscle, caused by stretch of the concentric muscle action. The stretch reflex happens when a quick stretch is detected in the muscles and an involuntary response occurs to prevent overstretching and injury. During plyometric exercise, a powerful concentric muscle action will follow quickly by an eccentric muscle action, such as when a person’s feet leave the ground in a squat jump.

Matz (2013) further added that the stretch-shortening cycle (SSC) is essentially the main system employed during the series elastic component (SEC). The SSC is broken down into three main phases as discussed below:

The first phase is the eccentric or stretching phase. This is also known as the preloading phase where the elastic components of the muscles and tendons are stimulated. As the muscles and tendons go through their quick shortening phases, the proprioceptors (muscle spindles) are stimulated and the elastic energy is stored.

The second phase is known as the amortisation or transition phase between the first and third phases. This is the time it takes for the signal to be sent from the propriorceptors to the central nervous system and back again to the necessary muscles to create a neuromuscular response. Ideally, this phase should be as short as possible. The third phase is the concentric or muscle shortening phase. This is when the action happens and the elastic energy is released and the muscle contracts creating a powerful, explosive action.

Chu (2004) explained that by adding plyometric exercises to one's athletic training programme, one will not only develop powerful, explosive muscles, but the person can also expect an improvement in the response time. It is referring to is making the second phase or the amortisation period as short as possible with as quick of a transition from the first and third phase. The faster the transition between the first and third phases the more the elastic components of the muscles and tendons are utilised and not lost as heat.

MacDonald (2013) indicated that when a quick stretch is detected in the muscles, an involuntary, protective response occurs to prevent over-stretching and injury. This response is known as the stretch reflex. The stretch reflex increases activity in the muscles undergoing the stretch or eccentric muscle action, allowing it to act much more forcefully. The result is a powerful braking effect and the potential for a powerful concentric muscle action. If the concentric muscle action does not occur immediately after the pre-stretch, the potential energy produced by the stretch reflex response is lost (i.e., if there is a delay between dipping down and then jumping up, the effect of the counter-dip is lost) (Harrison & Gaffney, 2001). It is thought that both the mechanicals model (series elastic component) and the neurophysiological model (stretch reflex) increase the rate of force production during plyometric exercises

Jastreboff 's theory is implied in this study because when a quickly stretched is detected in the muscles, an involuntary, protective response occurs to prevent over-stretching that can cause an injury to the athletes and it is known as stretch- reflex. Ideally, this process should be as short as possible. During plyometric training, if the concentric muscle action does not occur immediately after the pre-stretch, the potential energy produced by the stretch reflex response is lost. There is a great focus and emphasis on the change in force-velocity of a muscle to produce force or power during plyometric training.

Central Command Theory

The central command mechanism was first proposed by Zuntz and Geppert in 1886 for the control of ventilation and by Johansson in 1893 for the control of circulation (Nobrega, O'Leary, Bruno, Marongiu, Massimo & Crisafulli, 2014). It explained that central command consists of activation of regions of the brain responsible for somatomotor activation that also impinge on the cardiovascular control areas located in the medulla, mediating autonomic responses that are crucial for cardiovascular regulation during exercise. The pathways of the central command mechanism remain ill defined, although some details have been clarified. Klabunde (2007) added that an increase in heart rate and blood pressure are initiated at the same time skeletal muscle activity is attempted. Muscle tension development, however, does not appear necessary in order for these centrally mediated cardiovascular responses to occur; studies in which muscles have been paralysed by neuromuscular block and the signaled to contract have confirmed this. These studies demonstrate that even when the muscle could not develop tension; there was a diminished but significant increase in heart rate and blood pressure. In other words, the central command activation occurs independently of muscle contraction and for this reason, the mechanism sometimes is referred to as "feed-forward" regulation.

According to Moser (2008), central command theory stated that the initial cardiovascular response to exercise is stimulated by neural signals from the brain. Basically, it is the brain that causes the temporary adaptations to exercise. It suggests that the cerebral cortex is involved in signaling cardiovascular responses from the onset of exercise. Specifically, the motor cortex, which signals voluntary skeletal muscle contraction, sends efferent signals to the cardiovascular neuronal circuits in the medulla. These efferent signals generate an almost immediate increase in heart rate (and respiratory rate) via the autonomic nervous system as soon as muscle contraction begins. Accompanying these responses is an augmented blood flow to working skeletal muscle and away from less active tissue.

The implication of Zuntz and Geppert's theory on this study is that the initial cardiovascular response to exercise is stimulated by neural signals from the brain. It suggests that these efferent signals generate an almost immediate increase in heart rate through the nervous system from the onset of plyometric training and this may affect other cardiovascular variables.

Muscle Factor Model

The muscle factor model was introduced by Arthur Jones in the early 1970s as a revolutionary strength training method to body building and strength training (Richard, 2008). Jones studied muscle physiology for about 30 years and understood that the standard training methods were not completely consistent with how muscles function during exercise. Many of the training practices were rooted in tradition and contradictory to physiological facts. Jones has believed that training would be more effective if it were modified so that it worked in accordance with what was known about muscles. Jones figured that training programme based on how the body functioned would produce much better results than those training methods that ignored, denied, or were ignorant of the true workings of the body. Jones later named it Muscle Factor Model. Collier (2010) added that the muscle factor model is a key piece of the missing physiological information and will ultimately result in the integration of high volume and high intensity training. The muscle factor model may lead to the most significant changes and refinements in training since the introduction of periodisation back in the 1980s.

Tyler Robbins Fitness (n.d.) noted that muscle factor is a model that provides more complete explanation of how muscle fibers work during an exercise. Only muscle fibers that are active and overloaded during exercise will adapt and grow. The only way to overload a muscle fiber is to train it to a sufficient level of fatigue. Normally performed exercise programme usually do not train all or most of the fibers in a whole muscle due to the way muscle fibers are activated during exercise and because muscle fibers have widely varying levels of endurance. Collier (2010) suggested that the only way to maximise performance is to train all the muscle fibers that are active during the event; any untrained muscle fibers prevent the athlete from reaching his/her maximum potential.

Jones's muscle factor theory is implied in this study because he provided more complete explanation to how muscle fibers work during training. This new model suggests some significant modifications in training methods for sport in which strength, power, or endurance is important. In addition, he suggested that the only way to overload a muscle fiber is to train it to a sufficient level of fatigue. The only way to maximise performance is to train the muscle fibers using standard training methods such as lower and upper body plyometric.

Theoretical Studies

A Brief History of Plyometrics

Plyometric was created by a former Russian exercise scientists and a coach Yuri Verkhoshansky in the late 1960s (Art of Manliness, 2010). Verkhoshansky developed a system of exercises called "jump training" that used repetitive jumping in other to increase the speed and explosiveness of his track and field athletes. His first article about this training method was published in 1964 and his pioneering work eventually earned him the title of "Father of Plyometric" (MacDonald, 2013). Verkhoshansky in his studies, wanted to discover ways to develop the training abilities of his Olympic athletes. He then reasoned that since there seemed to be a correlation between short ground contact times and better performances in triple jumpers; this could imply that a greater stiffness could be the key to improved jumping ability. His athletes performed depth jumps focusing on reducing ground contact times, switching from eccentric to concentric action more quickly. Verkhoshansky experimented with many different exercises, but the depth jump appeared to be the best for duplicating the forces in the landing and takeoff. Glendinning (2014) expressed that the landing and takeoff were executed in an extremely short period of time, in range of 0.10- 0.20 seconds. As Soviet Union began to produce superior athletes in various sports including track and field events, gymnastics and power lifting, interest regarding this method increased.

The name “plyometric” has root from Greek word “pleythyein” which means to increase or augment and from the latin word “metrics” which means to measure (MacDonald, 2013). Although Verkhoshansky was deemed the “father of plyometrics”, he did not refer to it as such. He called it the “shock method” (Patalas, 2013). The term “plyometric” was coined by a former U.S. Olympic long-distance runner, Fred Wilt, who after watching the Soviets dominate the Olympics and other athletic competitions during the 60-70’s, decided to investigate how they were training. After spying on their methods, he started taking notes as he was convinced those happy jumps Soviet athletes were doing in preparation for their Olympic events were keys to their success (Yessis, 2000). It is a poor term to describe what happened but it has since been accepted and is now well established. Back in America, he decided to implement this method with his athletes and came up with the term “plyometric” (Art of Manliness, 2010). When Fred Wilt learnt of the work being done by Yessis (who visited and worked with Verkhoshansky in the early 80s) in the field of Russian training methods, they quickly teamed up to help disseminate information on plyometric. In addition to creating the shock method, Verkhoshansky is credited with developing the stretch-shortening concept of muscle contractions and the development of specialised (dynamic correspondence) strength exercises. Athletes around the world have used plyometric to become faster and more explosive. What makes this even more interesting is that this event took place during the Cold War era when sports rivalry was a serious thing (MacDonald, 2013).

Since its introduction in the early 1980s, two forms of plyometrics have evolved. In the original version of plyometric created by Russian scientists Yuri Verkhoshansky, it was defined as the shock method. In this, the athlete would drop down from a height and experience a “shock” upon landing. This in turn would bring about a force, involuntary 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 of time in range of 0.01- 0.02 seconds. The shock method is the most effective methods used by athletes to improve their speed, explosiveness and power after development of a strong base in strength training (Yessis, 2009).

The second version of plyometric, seen to a great extent in the United States, relates to doing any form of jump regardless of execution time. In addition, the time required for transitioning from the eccentric to the concentric contraction is much greater. Such jumps cannot be considered truly plyometric (as described by Verkhoshansky) since the intensity of execution is much lower (Yessis, 2000).

The term plyometric became very popular with the publication of many books on the subject matter. As a result, it is important to distinguish which type of “plyometric” exercise is used in order to determine its effectiveness and potential to receive the stated benefit. Rather than using the term plyometric to indicate exercises that utilise the shock method, it may be preferable to use the term explosive or true plyometric which can be considered the same as the plyometric originally created by Verkhoshansky (Wilt & Yessis, 1984). Most athletes execute simple and complex jumps and call them plyometrics rather than jump training as it was called in the past. However, even though the name plyometric is given to all jumps not all jumps are plyometrics (Witmer, 2011).

The Physiology of Plyometric: How it Works

Typical strength training exercises consist of relatively slow movements of longer duration designed to increase muscular strength and mass while plyometric training consists of quick, explosive movements designed to increase speed and power (MacDonald, 2013).Thus plyometrics are all about empowering the nervous system. During muscle contraction, the brain communicates with the muscles through the neuromuscular system. The faster this communication happens, the faster your muscles will contract and the faster you will move. But plyometrics work inside the muscle as well. Your muscles have different types of muscle fibers, there are slow twitch and fast twitch fibers. McArdle, Katch and Katch (2000) explained that we all have both fast and slow twitch dominant individuals. Some people are fast twitch dominant while others are slow twitch dominant and some muscles naturally favour one type over the other by default. Your muscles fast-to-slow twitch balance can be altered by the nature of the activities you engage as far as human nature and your individual genetics allow. The slow types are dominant in endurance athletes like long distance runners while sprinters are full of fast twitch fibers (Glendinning, 2014).

Plyometrics not only strengthen fast twitch muscle fibers but actually increase their quantities inside the muscles. Going back to how plyometrics work: making the stretch-shortening cycle happen as quickly as possible is the basis of all plyometric exercises.

A muscle that is stretched before a concentric contraction, will contract more forcefully and more rapidly, according to Carroll (2012). The stored energy is then released when the stretch is followed immediately by a concentric muscle action. The maximum force that a muscle can develop is attained during a rapid eccentric-contraction. However, it should be realised that muscles seldom perform one type of contraction in isolation during athletic movements. When a concentric contraction occurs (muscle shortens) immediately following an eccentric contraction (muscle lengthens) then the force generated can be dramatically increased.

Newton and Kraemer (1996) added that when a muscle is stretched, much of the energy required to stretch it is lost as heat, but some of this energy can be stored by the elastic components of the muscle. This stored energy is available to the muscle only during a subsequent contraction. It is important to realise that this energy boost is lost if the eccentric contraction is not followed immediately by a concentric contraction. To express this greater force the muscle must contract within the shortest time possible. A classic example is a “dip” just prior to vertical jump. By lowering the center of gravity quickly, the muscles involved in the jump are momentarily stretched producing more powerful movement. This whole process is frequently called the stretch-shortening cycle and is the underlying mechanism of plyometric training.

Three Phases of Plyometric Training

There are three distinct phases involved in plyometric training namely: eccentric or loading phase, amortisation or transition phase, and concentric or unloading phase stated by Arazi and Asadi (2011).

The Eccentric Phase

The first stage of a plyometric movement can be classified as the eccentric phase, but it has also been called the deceleration, loading, yielding, countermovement or cocking phase. This phase increases muscle spindle activity by pre-stretching the muscle prior to activation. Potential energy is stored in the elastic components of the muscle during this loading phase slower eccentric phase prevents taking optimum advantage of the myotatic stretch reflex.

The Amortisation Phase

This phase involves dynamic stabilisation and is the time between the end of the eccentric contraction (the loading or deceleration phase) and the initiation of the concentric contraction (the unloading or force production phase). The amortisation phase sometimes referred to as the transition phase, is also referred to as the electromechanical delay between the eccentric and concentric contraction during which the muscle must switch from overcoming force to imparting force in the intended direction. A prolonged amortisation phase results in less than-optimum neuromuscular efficiency from a loss of elastic potential energy. A rapid switch from an eccentric contraction to a concentric contraction leads to a more powerful response.

The Concentric Phase

The concentric phase (or unloading phase) occurs immediately after the amortisation phase and involves a concentric contraction, resulting in enhanced muscular performance following the eccentric phase of muscle contraction. This occurs to enhanced summation and reutilisation of elastic potential energy, muscle potentiating and contribution of the myotatic stretch reflex (Coach Colleague, 2009).

Types of Plyometric Exercise

There are two major categories of plyometric exercises namely; plyometrics based on the body affected and plyometrics based on the sports-specific. Examples of plyometric based on the body affected are lower body plyometrics and upper body plyometrics while examples of plyometrics based on sports-specific includes; rhythm, power, speed and individualised plyometric exercises. According to Ebben (2009), types of plyometric exercises include:

Lower Body Plyometric

- **a.** Double and Single Leg Hops
- **b.** Power Skipping
- **c.** Power Bounds
- **d.** Hurdle Hops
- **e.** Standing Triple Jumps
- **f.** Box Jumps
- **g.** Single Jumps
- **h.** Depth Jumps
- **i.** Single Leg Tuck Jump
- **j.** Squat Jumps
- **k**. Jump to Box
- **l.** Lateral Jump to Box
- **m**. Tuck Jump
- **n.** Split Jump
- **o.** Bounding
- **p**. Zig Zag Hop
- **q.** Lateral Hurdle Jumps
- **r.** Bounding with Rings

Upper Body Plyometric

- **a.** Power Push-Ups
- **b.** Wheelbarrow Walks
- **c.** Overhead Throws
- **d.** Over Back Toss
- **e.** Explosive Squat Throws
- **f.** Single Arm Overhead Throws
- **g.** Medicine Ball Throws
- **h**. Twist Tosses
- **i**. Slams
- **j.** Side Throws
- **k.** Squat Throws

There are many plyometric exercises for both the upper and lower body. As with other forms of sports training, exercise selection should mimic the movement patterns of the sport as closely as possible. Walker **(**2013**)** stated that not all plyometric exercises are equal in intensity, skipping exercises for example, are relatively light while single leg bounds and depth jumps are the most intense. A programme should progress gradually from lower intensity drills to more advanced plyometric exercises particularly in an individual with less strength training experience. The number of plyometric exercises is typically kept to a minimum also. A typical session may contain only two or three lower body plyometric exercises interspersed with upper body plyometric drills if they are appropriate for that sport. Correct exercise selection is essential, while there are many plyometric exercises but only a few will be suitable for any one particular sport or event.

Lindsey (2014) explained that lower body plyometric exercises are suitable for many sports such as basketball, tracks and field athletics, sprinting, soccer, hockey, rugby, baseball and so on. In fact, performance in any sport that involves jumping, sprinting or kicking can be improved with lower body plyometric exercises. These lower body plyometric exercises can be used to develop power in any sport that involves sprinting, jumping, quick changes of direction and kicking etc. They are most effective when completed in conjunction with a suitable strength training programme or following a phase of maximal strength training. There is no evidence to suggest the risk of injury is increased during plyometric training in adults. However, as a precaution, several safety guidelines have been recommended to keep plyometric exercises as safe as possible. Because plyometric has received little scientific study compared to conventional strength training, there are no definitive guidelines regarding sets, repetitions and frequency etc. The National Strength and Conditioning Association and other experts in the field of exercise physiology have proposed parameters that will help coaches and athletes design an effective training plan (Mackenzie, 1997).

Table 1: Plyometric drills and their intensity

Types of Exercise	**Examples**	**Intensity**
Standing based jumps performed on the spot	Tuck Jumps Split Jumps Squat Jumps	Low
Forward jumps from standing	Bounds and hops over 10 to 20 meters	Low to Medium
Multiple double leg hops from standing	5 bounds 6 bunny hops Double footed jumps over hurdles Double footed jumps up steps	Medium
Multiple single leg jumps from standing start	Single leg hops up stadium steps	High
Drop jumps	2 x 6 jumps for height or distance	High
Speed bounds	4 x 20 meters	High
Multiple jumps with run up	3 x 2 hops and jump into sand	Very High

	pit with a 5 stride approach 2 x 10 bounds with a 5 stride approach	

(Mackenzie, 2000)

Upper Body Plyometric Exercises

Performance in sports such as basketball, volleyball, softball, baseball, tennis, badminton, golf and the throwing events in athletic can benefit from upper body plyometric exercises. Also certain position players such as goal keepers in soccer will find these drills useful. Most upper body plyometric drills require the use of a medicine ball.

Walker (2013) explained that these plyometric drills are used to develop explosive power in the upper body. There are several different methods of power training. The simplest is to perform classic weight lifting exercise, such as bench presses, as explosively as possible. The problem with this method is that the barbell has to be decelerated at the end of the movement so the lifter can keep control of it. Gambetta (2007) added that these upper body plyometric drills allow maximum power to be generated because, unlike barbells or dumbbells, the medicine ball can be released into the air.

Racket games such as tennis, badminton and squash, the throwing events in athletics, basketball, volleyball, rugby, football, the martial arts and wrestling all require upper body power. Plyometric drills can be used to convert an athlete maximal strength training into sport- specific power helping to further improve performance. Plyometric has not had the same level of scientific study compared to traditional strength training. As there are no definitive guidelines regarding volume, intensity and frequency etc. However, the above guidelines have been set out by leading authorities in the field.

Types of Plyometric Exercises Based on Specific-Sports

There are three general types of plyometric exercise, rhythm, power, and speed. Each form develops different qualities of the neuromuscular system. As such, some exercises are better suited to different events. According to Carroll (2012), some events required all the three types of drills which may include the following:

Rhythm Plyometrics

Rhythm plyometrics help to develop the coordinated movement skills required in track and field. Their primary purpose is to give the athlete greater kinesthetic awareness or body sense, coordination and rhythm. They promote general athletic ability and performance. All track and field athletes benefit from these drills, but they are especially well-suited for less mature athletes and those without good natural skills. For example, many young distance runners have undeveloped strength, rhythm and coordination. For them, the greatest contribution of plyometric drills is to increase their coordination and sense of rhythm. Rhythm plyometrics are quite useful in developing correct running mechanics. More importantly, these drills give the young athlete an improved sense of physical awareness, how his/ her body moves through space. This applies to all athletes. Rhythm drills for sprinters and hurdlers are crucial to optimal success. Sprinting and hurdling are events where speed and power are expressed through proper technique and rhythm.

Jumpers, too, need rhythm plyometric; jumping events involve an explosive movement at the end of a controlled run-up. A smooth rhythm enables the athlete to convert run-up speed into the jump. Even High School throwers need rhythm and coordination. The discus is an event of smooth rhythmic motion building to an explosive release. And Shot Putters need to have a sense of rhythm that enables the athlete to convert run-up speed into the jump with the feet in order to move across the throwing circle and land in a solid power position (Gambetta, 2007). Rhythm plyometric exercises also serve as a bit of physical education. As funding and support for physical education curricula have eroded, many young high school athletes come to sports programmes with poor coordination, movement skills, and basic strength. This fact is particularly applicable to a track and field, which usually has greater numbers and variety than most other school sports teams (Ebben, 2009). Rhythm plyometric drills are mostly simple movements done repeatedly. Generally, they involve segments of the movements athletes use while running, jumping or throwing. Some common rhythm drills are skipping, jumping rope, cross-over steps, running with high knee, rhythm bounds, running kicks, butt kicks, fast feet running, and cariocas. These drills develop the necessary techniques and coordination to let speed and power be expressed most efficiently (Chu, 1998).

Power Plyometrics

The primary goal of plyometric training is to increase power. Collier (2010) expressed that the track and field athletes that need to stress power development are mostly jumpers and throwers, so their training should utilise a large number of plyometric power drills. Throwers should use power plyometric for the upper body as well as the lower body. Jenny (2012) expressed that although athletes in all events should use power drills in their training at different points in the season. A coach must bear in mind that power movements are physically demanding, sufficient rest is mandatory both within and between workouts. During the most competitive part of the season, these exercises should be tapered down. Power exercises for distance runners need to be closely monitored to avoid overtraining during high volume periods.

De Villarreal, Izquierdo and Gonzalez-Badillo (2011) expressed that power plyometrics emphasise the simultaneous application of maximum strength and quickness. The focus of movement is explosiveness. When performing jump repetitions, for example, the objective is to perform a set of jumps at high intensity, not to continue repetitions past the point of fatigue. Although plyometric training can be used for such purposes, the goals of power drills are not endurance.

Explosiveness is greatest when the muscle is warmed and rested. Do an exercise only to the point where performance declines. It is better to do an extra set of an exercise than to add repetitions that are not done powerfully. Power plyometric drills include a variety of jumping movements – hops, bounds, single jumps and leaps. Upper body exercises include medicine ball throws, pendulum throws and push-ups. Depth jumps and box jumps are advanced plyometrics, but are risky for most high school athletes.

Speed Plyometrics

Speed plyometrics emphasise the speed component of training. The over-load principle is satisfied in the form of increased speed rather than force. In other words, movements are performed significantly faster than normal. The objective of speed-assisted, or over-speed, training is to force the neuromuscular system to respond more quickly to a stimulus. The accelerated time frame of the action overloads the system, creating faster than normal response. This training effect then carries over into increased event speed. Speed exercises obviously apply to sprint and hurdle events. Maximising running speed is the key to success in these events. Jumpers, too, rely heavily on sprint speed, most notably long jumpers and pole-vaulters. Throwers benefit from speed training through improvements in general quickness. Speed plyometrics for distance runners is beneficial, but one should remember to coach them to be fast distance runners, not sprinters. The focus should be running mechanics as opposed to sprint speed. Many of these drills will be the same as those done for rhythmic development, stressing maximum quickness. Fast skips, arm swings, and butt kicks are a few examples of speed plyometric exercises.

Using Plyometrics for Power Endurance

Although the primary goal of plyometrics is to develop explosiveness, athletes also gain by training for power-endurance. Long sprinters and those who compete in multiple events need to develop the capacity to be explosive repeatedly. Further, Gaudette (2014) added that all athletes gain from building a foundation of strength and sub-maximal power. Such preparation prevents injuries and allows for greater intensity and quality in training. Generally, power plyometrics should be performed with four-eight repetitions at maximal effort. Exceeding that number diminishes the specificity of the exercise for explosiveness (Markstrom & Olsson, 2013). With greater number of repetitions, however, a power-endurance effect is achieved. It is not too unlike speed-endurance running for sprinters and middle-distance runners. Where sprinters train to maintain speed over distance, athletes can also train to be powerful over time. Repetitions from 8 to 20 or more and distances from 40 to 150 meter fall in the endurance category.

There are other benefits to the use of plyometrics for power-endurance. Multiple repetitions of low stress exercises often serve as good introduction to plyometric training. Young athletes can learn the jumping movements and techniques easily when they focus solely on the movement without having to concentrate on the explosive element. The conditioning effect of these multiple repetitions also builds strength in athletes and prevents injury as the intensity of the exercise increases. Finally, as a practical consideration for the High School coach, somewhat less supervision is needed to accommodate a fairly large portion of your team.

Individual Plyometric Exercises

As with any training programme, there is no single regimen of plyometric exercise which will guarantee optimum performance from the athletes. The particular exercise is often much less important than how it is executed. In fact, the same basic movement performed differently can develop rhythm, power or speed, considering skipping, for example. Markovic (2007) expressed that the successful application of plyometric hinges on proper training the stretch-reflex and elastic qualities of the muscles involved. The emphasis is upon explosive reaction in response to the active-loading of the muscle. Many exercises can be made plyometrics. Many coaches will discover a drill that seems especially well suited to their athletes; facilities and environment. The following listing and description of various plyometric exercises are not intended to be exhaustive. These drills are strongly recommended, however, and should be adequate for High School athletes; rhythm skipping, high knee running, jumping rope, butt kicks, running kicks, skipping kicks, rhythm jumping to mention but a few.

Benefits of Plyometrics

There are many benefits of plyometrics, which include the following according to Elite Athletic Performance (2013):

1. **Enhance Performance**: Since plyometric can boost one's running speed, one's performance can improve a lot. Even if someone are involved in an activity that does not involve running, plyometrics can still help that person, because one can be better at throwing farther or punching harder. Plyometric training can help one achieve almost all athletic goals.
2. **Enhanced Muscular Power and Speed:** In sports performance, the most important element is power. Power is the amount of force which can be generated in the shortest time frame possible. In a layman terms, this is the speed of muscle contraction. Power is determined by the time it takes for muscular strength to convert into speed. A short, fast muscles contraction will produce higher energy than slower and more powerful contraction. Increasing muscular power by quickly converting muscular strength into speed gives athletes the ability to perform movements that strength alone cannot allow. Therefore muscular power and muscular strength are not the same Power= Mass x Speed /distance.

Plyometric improves the ability to apply more force, more rapidly. This ability to generate maximal force can be transformed into a sports-specific power in sports like martial arts, soccer, tennis, and basketball and athletic. This is achieved through plyometric exercises that rapidly stimulate the elasticity of muscles with movement that mimic the sports. With plyometrics, the strength of the arm and leg muscles would be enhanced by a higher rate of force development, thereby guaranteeing a rise in muscles power and force.

3. **Burns Calories and Reduces Weight**: As the muscles become bigger, stronger and improve in its endurance capabilities, the calories will be burnt at a higher rate. Plyometric exercises with increase metabolism thereby burning more calories even when at rest. Since muscle maintenance needs more energy than fat maintenance, the individual will burn more calories with each activity.
4. **Plyometric Enhance Power Endurance:** Power is an important performance indicator and when this type of endurance is developed, the individuals are able to perform at a higher intensity for longer time. Plyometric training can also teach the endurance athlete to produce muscular force more efficiently; this efficiency is realised through the body learning to produce more force for less energy expenditure. Thus this saving in energy cost can be recouped towards the end of endurance type of activity i.e. the energy saving made during the beginning of the competition is now available in abundance for the end of game. It is this that makes it possible for endurance athletes to benefit from doing plyometric training.
5. **No Extreme Exercising Equipment is needed:** Exercise equipment can be expensive, and plyometric exercising does not require any. Plyometric does not require an individual to buy any such equipment. Anything that is needed could be easily found lying around the house or office to complete your exercise routine with them.
6. **Easily Calibrated to Suit anyone's Needs:** Plyometric exercising can be calibrated according to anyone's needs. An individual can be as simple as jumping on trampoline several times a day or even using your old jump rope. For someone looking for a little more intense workout, perhaps jumping back and forth from a lower platform to a higher platform would suit their needs. There are many ways to increase the intensity of the exercise by

simply increasing the distance or height of each jump. Plyometric exercising is simply utilising the muscular energy that it takes to jump to your own exercising advantage. The right plyometric training depends upon the individual's needs and fitness levels.

7. **Benefits to Tendon:** In other to increase the power and speed of muscular movements, an individual needs to increases the strength of your tendons. Moreover, stronger tendons mean fewer injuries some to undergo surgery because they tore a tendons while playing soccer or basketball. They might have been able to avoid those injuries had they only worked on increasing strength and elasticity in their tendons. Plyometric strengthens the tendons and boost their elasticity by placing stress on them in a controlled setting.

8. **Decrease Injury:** In many sports the highest incidences of injury is when the joint or system is decelerating. Plyometric training not only teaches the body to produce force more effectively, it also teaches the body to control and absorb forces safely. Reasonably recent research has found that women are two to three times more likely to suffer an ACL (anterior cruciate ligament) injury than men (MacCadam, 2014). Interestingly enough they also found that plyometric training is one of the best method of protecting female athletes from this form of injury.

9. **Greater Recruitment of Muscle Fibers:** In an untrained person, normally not all the potential motor units that can be activated in a given movement are recruited. For example if there are 10 motor units available to the athlete in a jumping movement, under normal conditions, only 5 might be recruited to perform the movement. The limitation here is neural activation- the nervous system has to be trained to switch on. By training the body in a plyometric way, the body makes demand on the muscular system, whose needs are met first by the nervous system. The body now learns to recruit more motor units for that specific

activity or movement. With more motor units coming to your aid, this will increase the force produced for that action.

10. **Benefits to all Athletes**: All athletes involved in speed and power dominated sports for example soccer, basketball, hockey, rugby, martial arts, tennis, racket games, track and field to mention but a few can get benefit out of high intensity, low volume plyometric training (speed and vertical) as well as low intensity, high volume plyometric training. It can also benefit endurance athletes (middle and long distance runners, triathletes, swimmers etc.) and even bodybuilders, as a form of cardiovascular training. All athletes can therefore benefit from plyometrics. Even bodybuilders can experience better flexibility. Power lifters can experience slight increase in agility and a small increase in poundage, but at their level-pound increase can mean a win or a loss.

Rohmann (2013) also affirmed that basketball players can greatly benefit by increasing their vertical jump, adding strength to their legs and increasing the endurance factor for all those countless jumps on courts. By following the upper body workout, boxers can increase their flexibility and endurance in their upper body to help them take advantage in those late round moments where it is all on the line.

Aside from professional and amateur athletes, everyone else can benefit. Small children perform plyometrics unknowingly on the play ground every day. In turn they are more flexible, healthier and active. Schwartz (2014) expressed that elderly individuals can greatly benefit by doing a slower, less intense of the workout but still getting the good flexible and energetic effects.

Plyometrics Basic Considerations

Plyometrics training is a great tool for improving an athlete’s speed, power, explosiveness, elasticity, eccentric strength and other aspects of the neuromuscular system such as rhythm, balance, proprioception, movement coordination and agility (King, 2012). However, a poorly constructed plyometric programme can hinder performance and even lead to injury. Coach Colleague (2009) explained that although plyometric training is generally accepted as a training method, it does have detractors. Because of its ballistic nature, plyometrics used improperly can easily lead to injury or over-training. A coach must be especially attentive and careful to ensure that plyometrics are used correctly. According to American College of Sports Medicine (2009), the following points below should be taken into consideration before working with any young athlete:

1. **Age:** The age of an athlete plays a significant role in determining how much plyometric he/she should do. Jumping around is pretty stressful on the joints, tendons, central nervous system, and muscles. If you are a younger athlete and still growing, you should try and limit the total plyometric work load you are undertaking. Ideal Health Fitness (2009) explained that excessive plyometric on young athlete can impede the proper development of their joints causing long term effects. Conversely, once you reach a certain age, usually around 35 to 45, you should also start to examine closely how much jumping you are doing. There is a great saying that goes "you are only as old as you feel". This is excellent to keep in mind if you are older athletes.
2. **Basic Strength**: The overload of the muscular system by the combination of the body weight and gravity requires a basic level of strength to ensure against injury when performing explosive movements. Opinions vary as to the degree of strength needed. Some authorities suggest that the most rigorous forms of plyometrics, such as depth jumps and one-legged box jumps, demand that an athlete be able to squat 150-200% of his or her body weight. This standard would not be met by the great majority of high school athletes. Two rules of thumb apply here. First, athletes should start with the most general and lowest level of plyometric exercises. Low intensity and limited repetitions are suggested

for beginners and younger athletes. The coach must also take the athlete's body weight into consideration. The same drill will produce more physical stress upon the heavier athlete. In adolescence, strength in relation to body weight is often poorest among those who are heavier. Second, if the athletes are capable of performing the exercise explosively with correct technique, their strength is probably adequate for the particular exercise. If they are not capable of performing the task properly, or execution breaks down after a few repetitions, then the athletes need to develop greater basic strength before moving on to more advanced drills. This cautionary note is especially appropriate for young athletes, who are usually in a hurry to do the most advanced work first. Remember, the key to plyometric training is technically correct, explosive movement. Doing the exercise improperly only subjects the athlete to the threat of injury.

3. **Environment:** The type of environment where a coach conducts the plyometric training sessions will dictate the type of programme the coach will construct**.** For our purpose, environment means spacing, flooring and equipment. An ideal setting for plyometric training is an area with good spacing, soft flooring such as grass or turf to alleviate tension on the ankle and knee joints, and equipment such as a box or hurdle. These conditions allow you to progress your athlete, group or team in a safe and efficient manner. If the environment is not ideal (i.e. hard surface) consider minimising the volume and intensity of jumps and avoid ones that require deep hip and knee flexion.
4. **Good Technique and Stability**: Stability and technique are the foundation of plyometric/ jump training. Plyometric training places tension on the ligaments and joints of the lower extremities. Thus, having stability is important to withstand the forces created by jumping. Stability is achieved partly by using proper technique. Athletes need to understand and demonstrate proper trunk control and hip and knee flexion upon landing, especially on

jumps with a concentric emphasis. Being technically sound is also vital for efficiently using the stretch-shortening cycle. The better position athlete can put his body in, the more prepared he is to use his elastic abilities and execute multiple jumps. Demonstrate and clearly explain the proper execution of an exercise before you permit the athlete to begin.

5. **Rate vs**. **Degree of Stretch**: A corollary to the previous observation is that the rate of stretch is more important than the degree of stretch. It is better that an athlete do a jumping movement in a quick, bouncy manner rather than slowly sinking to a low squat and then rebounding. Doing jumps slowly is not plyometric and lessens the effect of training. The goal of plyometric training is to increase power. Therefore, the emphasis should be on reacting explosively immediately upon contract. This is the kinetic moment that you are training. The execution of the exercise should be forceful, but most importantly, done quickly. No gathering should take place before the explosive response.
6. **Central Nervous System Capability:** Incorporating plyometrics training requires certain demands on the central nervous system (CNS). An athlete with a low work capacity engaging in plyometric training is a recipe for disaster. The CNS will get fried and the athlete will have a very difficult time getting a quality workout. In addition, a long recovery time will be needed. Athletes with a low work capacity should only participate in low-level plyometric drills that require low CNS demand, thus only needing a shorter recovery period. Only as the athlete progresses and develops a better “metabolic engine” should the coach implement plyometric exercises requiring more CNS activation (i.e. depth jumps) (King, 2012).

Plyometric Safety Tips

Plyometric training just like other training methods is full of risk if not done properly.

Quinn (2013) offered the following guidelines to reduce the risk of injury which include:

1. Use only low intensity and low volume plyometric drills, with caution, for athletes over 240 pounds (109kg).
2. Athletes must be well-conditioned and have good levels of physical strength, flexibility and proprioception (in body awareness) before commencing plyometric training.
3. Athletes must be instructed on the proper techniques before commencing any plyometric exercises such as the landing techniques and land softly to absorb shock.
4. Landing surfaces should be shock absorbing for depth jumps such as gymnastics rubber mats, suspended grass. Hard surfaces should never be used.
5. Plyometrics are recommended only for well-condition athletes.
6. You should have high levels of leg strength prior to performing plyometrics.
7. Warm up thoroughly before starting plyometrics.
8. Allow plenty of rest between plyometric workouts.
9. Pay attention to injury warning signs.
10. Use footwear with plenty of cushioning.
11. Stop immediately if you feel any pain in your joints.
12. Wear shoes that provide good ankle and arch support, and a wide, non-slip sole, such as a basketball or aerobic shoe. Do not perform plyometrics while wearing running shoes.
13. Use only plyometric boxes that are sturdy and have a non-slip top.

14. Athletes who do not respond well to the instructions of coaches are also at greater risk of injury, under or over training should use plyometric with caution, if at all.

Guidelines for Planning a Plyometric Session

According to Carroll (2012), the choice of exercises within a session and their order should be planned thus:

a. Begin with exercises that are fast, explosive and designed for developing elastic strength e.g. low hurdle jumps; low drop jumps.
b. Work through exercises that develop concentric strength (standing long jump; high hurdle jumps).
c. Finish with training for eccentric strength (higher drop jumps)

An alternative session could be:

i. Begin with low hurdle jumps
ii. Progress to bounding and hopping
iii. Continue with steps or box work
iv. Finish with medicine ball workout for abdominals and upper body.

A thorough warm-up is essential prior to plyometric training. Attention should be given to jogging, stretching, striding and general mobility especially about the joints involved in the planned plyometric session. A cool down should follow each session.

It is wise not to perform too many repetitions in any one session and since it is a quality session, with the emphasis on speed rather than endurance, split the work into sets with ample recovery in between. An experienced athlete conducting lower body plyometrics may conduct up to 150-200 contacts in session-athletes new to plyometric work should start with low to medium intensity exercise with around 40 contacts per session e.g. two sets of six bunny hops is 12 contacts.

Similar approach should be taken with upper body plyometrics. The focus must always be on quality and not quantity.

Conditioning Athletes using Plyometric

Twist (2010) under conditioning athlete using plyometric explained that the body needs movement, balance and strength to work in concert to produce skillful performance. Only an integrated training approach that encompasses all of these characteristics will truly maximise the potential of the human machine. The Twist paradigm is based on a neuromuscular and proprioceptive training style that fosters a fast and accurate mind-to-muscle contraction, resulting in smart muscles that intuitively comply with the mind's commands. The outcome is a bigger, faster, stronger and smarter athlete.

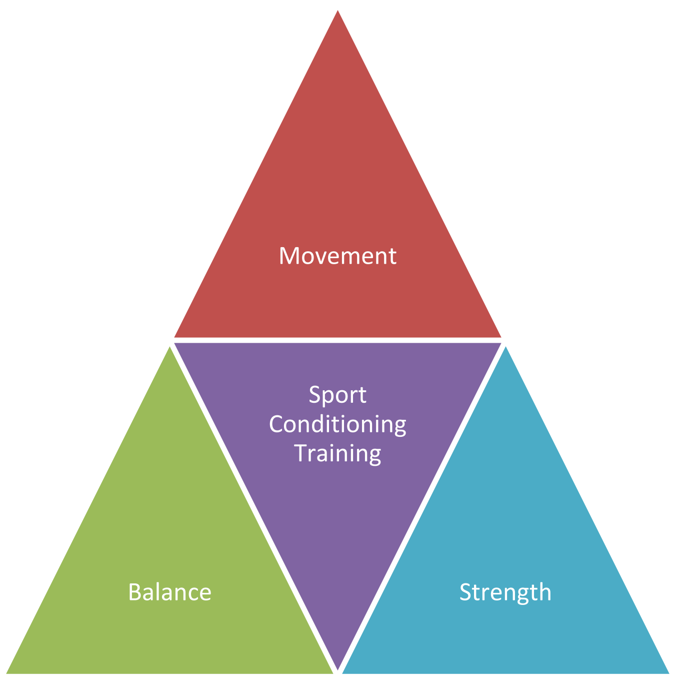

Fig. 1: Conditioning athletes using Plyometric (Twist, 2010)

Plyometric moves are "sexy"- cool drills- and they are well received by athletes, so there is a tendency to adopt them without qualified coaching. But the risk is higher with this type of workout; safely upgrading to explosive power requires a knowledge foundation, a functional body and precise performance coaching. These are not drills to insert randomly into boot camps and other workouts without a teaching system.

Do not build power on dysfunction, and do not ramp up aggressive power drills without the critical eye to make mechanical adjustments. To progress athletes and other clients safely and effectively using training that increases in complexity and intensity requires a clear understanding of appropriate progressions and regressions to minimise risk while maximising results.

1. **Focus on the Foundation**

When an athlete begins to train, focus initially on developing an athletic foundation (movement, strength, and balance). Accomplish this by enhancing the mobility and stability link so the athlete achieves full ranges of motion and establishes maximal joint stability and leverage; this will allow him to control the forces and movement on the joints as the intensity and complexity of the training increase.

2. **Foundation to Function (F2F)**

Next, work on executing the neuromuscular and functional skills necessary for power development. Do this by increasing the complexity and neural demand of exercises, while maintaining a focus on the body control needed for the unpredictable demands that today's athlete must regularly confront: for example, deceleration, directional changes and body contact.

3. **Function to Performance (F2P)**

With the power foundation established, the evolution of power production can begin. Before teaching an athlete how to accelerate and generate explosive force, teach him how to absorb force by harnessing power using deceleration training. To have the best application to sport, power production must be tested using multidirectional movements (i.e., hard cuts, evasive tactics) so the athlete learns how to maintain power through direction change. To reach his full athletic potential, an athlete must be able first to harness power, then to produce it; and finally to maintain power production.

4. **Performance to Podium (P2P)**

When an athlete has developed his abilities to produce power, to demonstrate whole-body balance and to move efficiently, focus more on the high-level conditioning and training challenges that will progress him from an execution and performance focus to a true elite-level training focus.

Plyometric Exercises: Position Statement

It is the position of the National Strength and Conditioning Association (1993) that:

1. The stretch-shortening cycle, characterised by a rapid deceleration of a mass followed almost immediately by rapid acceleration of the mass in the opposite direction is essential in the performance of most competitive sports, particularly those involving running, jumping and rapid changes in direction.
2. A plyometric exercise programme that trains the muscles, connective tissue and nervous system to effectively carry out the stretch-shortening cycle can improve performance in most competitive sports.
3. A plyometric training programme for athletes should include sports-specific exercises.
4. Carefully applied plyometric exercise programmes are no more harmful than other forms of sports training and competition, and may be necessary for safe adaptation to the rigors of explosive sports.
5. Only athletes who have already achieved high levels of strength through standard resistance training should engage in plyometric drills.
6. Depth jumps should be used by a small percentage of athletes engaged in plyometric training. As a rule, athletes weighing over 220 pounds should not perform depth jump from platform heights higher than eighteen inches.

7. Plyometric drills involving a particular muscle/joint complex should not be performed on consecutive days.
8. Plyometric drills should not be performed when an athlete is fatigued. Time for complete recovery should be allowed between plyometric exercise sets.
9. Footwear and landing surfaces used in plyometric drills must have good shock-absorbing qualities.
10. A thorough set of warm-up exercises should be performed before beginning a plyometric training session. Less demanding drills should be mastered prior to attempting more complex and intense drills.

Seasonal Training using Plyometrics

Plyometric training for true speed and power enhancement is best applied in the off-season programme when training an athlete. Rogers (2008) explained that after initial phase of force absorption training in order to prepare the tendons (especially important in older athletes or athletes with significant training age), retrain patterns for optimal technique and reacquaint the athlete with the skills inherent to plyometrics. This initial phase will generally take two-six weeks, depending on the individual. Plyometrics can be introduced as part of in-season training, but the force absorption part of the pattern must be curtailed. Jumping up onto boxes and jumping with assistance using rubber bands are both excellent methods for in-season plyometric training. Preseason is generally a time to focus on group and team techniques and sport tactics; there are so many demands on an athlete’s time and energy that is better not to introduce additional training.

According to Sports Training Advisor (2014), during the week, plyometrics should be used early after a rest day or when the athlete is coming off a recovery day in which the focus was to prepare for quality work. In the training session itself, assign plyometrics early to increase neural recruitment of the muscle bundles. In a team sport, it is imperative to assign the athlete some plyometric-type of activities or tempo sprints in order to leave the nervous system "feeling fast" in movements similar to the ones trained during the day's season. For example, try box jump-ups after squats, rubber-band quarter squat jumps after heavy jerks or push presses or tempo sprints after any type of medium-to-heavy leg training for athlete who lifts heavy weights and needs to accelerate and sprint fast. This helps to reset the nervous system so that it feels fast after the workout.

Types of Fitness Training for Sports

Numerous types of fitness training exercises and regimens can improve performance in sports. The correct combination of activities should build the fitness components that are keys to high performance in each sport. Short bursts of speed for basketball tap different energy systems than long, sustained marathon running, so the exercises and other variables must be manipulated to fit either type of training. According to Sports Training Adviser (2014), few examples of types of training activities that build sport fitness include:

1. **Continuous Training Method (Aerobic Training)**: This type of exercise is, as the name suggests, continuous. Rests are not allowed. Continuous training refers to aerobic activity performed at 60 to 90% V02max for at least half an hour with a minimum of three training sessions per week. To achieve this you must exercise at a constant rate which is within your aerobic training zone (60-80% max heart rate). Continuous training should last for bouts of at least 20 minutes (when starting) up to 2 hours or more (think of a marathon). Aerobic training is physical exercise of low to high intensity that depends primarily on the aerobic energy- generating process. Aerobic literally means relating to, involving, or requiring free oxygen, and refers to the use of oxygen to adequately meet energy demands during exercise

via aerobic metabolism. Generally, light-to-moderate intensity activities that are sufficiently supported by aerobic metabolism can be performed for extended periods of time. Examples of cardiovascular/aerobic exercise are aerobics, medium to long distance running/jogging, swimming, cycling, and walking. When done at the lower end of this range, it is often referred to as long, slow distance (LSD) training. This level of training is ideal for those athletes starting off an exercise programme and those wishing to maximise burning calories for weight loss.

2. **Anaerobic Training Method**: The energy system has two path ways for producing energy for muscle action. The first is called the "alactic" system (does not produce lactic acid as the by-product). The alactic system uses creatin phosphate as its fuel source. It is primary system used by short sprinters, jumpers and throwers in fact any activity lasting up to 10 seconds. The second anaerobic energy pathway is called "lactic" acid system (produce lactic acid as the byproduct of energy production) and uses the rapid break down of glycogen for its fuel. 400m and 800m athletes rely heavily on the lactic acid system and to lesser extent the 200m also.

3. **Interval training:** Interval training is a type of exercise that combines set intervals of extremely high intensity activity to improve both aerobic and anaerobic fitness with periods of lower level activity such as walking or light jogging. Interval training is also known as high-intensity interval training (HIIT) (Power & Howley, 2001). Combining these short, fast bursts of high intensity activity with longer periods of low intensity sustained activity confers many benefits. Almost any type of exercise can be made into interval training. Performing ten 80metre sprints in ten seconds with a 60 second recovery is an example. In training for sprints, for example, the exercise intensity or maximum effort should remain unchanged and the recovery period should be at least three times longer than the training interval. Coaches

can also use interval training for longer events. If athletes were training to run 10 km run in 40 minutes, they could begin by running 1 km in 4 minutes, have 4 minutes rest, then run another and gradually build up from this. This type of training is usually alternated with other training methods, for example, athletes may run like these two nights a week and spend the third session taking a longer, slower run.

4. **Circuits Training Method:** Circuit training is a great way to build a broad range of exercise and skills, particularly for large groups of athletes. Circuit training was originally designed to improve general fitness (GF). It has been developed to improve strength endurance (SE), for endurance athletes, and power endurance (PE) for sprinters and jumpers. The basic premise behind circuit training is that athlete takes a number of exercises (6-12) and performs each one after the other until the circuit is completed. Circuits feature multiple stations where athletes perform assigned activities for specific periods of time, or until they have completed a set number of repetitions. After finishing at one station, and they rotate to the next. General fitness circuits are usually performed using body weight. Strength endurance and power endurance circuits are performed using resistance methods. When using resistance, it is advised that athlete should use loads of 30-70% of your 1RM.
5. **Weight or Resistance Training Method:** Weight or resistance training method focuses on building up strength, power or muscular endurance by exercising muscles against a resistance. Barbells, resistance bands, machines and other types of equipment that offer resistance can build strength with even the athlete's own body weight

The following are the examples of strength training methods thus:

a. **Reactive Strength Method:** Most athletic movements are performed by first lengthening the muscles before it is shortened. When this lengthening and shortening is performed quickly the subsequent concentric action is more powerful. Between the lengthening and the shortening there is time lag, during the time lag energy is lost and the subsequent movement is not as powerful as it might have been. Reactive strength training, improves the body's ability to lessen the lag time between the lengthening and the shortening phases of muscle contractions. It also teaches the body to use the stored energy which is latent in every action. Activities such as depth jumps, hops and repeated hurdle jumps collectively called "plyometric" is used in track and field training method.

b. **Explosive/ Dynamic Strength Training:** Explosive/Dynamic strength is the work that is done explosively. It is done in such a way that there is an acceleration of the extension at the end of the movement. As a consequence, there are number of ways to achieve this acceleration. You can attach rubber bands to lifting bars, which ensure the athlete has to work very hard into full extension. You can perform a jumping motion at the end of the movement as in "jump squat". You can simply work at a very high tempo (through the full range of movement). Because of the wide variety of exercise modes, load can vary wildly from 30-85% of your 1RM, but never more than five repetitions is performed in a set.

c. **Plyometric or Jump Training:** Plyometric training is a type of training in which eccentric muscle contractions quickly follows concentric contraction (ACSM, 2009). It is an excellent method for building power, reactions, coordination, and explosiveness, as well as the stretch-shortening cycle due to the rapid stretch of the muscle during rebounding after landing. It's like stretching fully a coiled spring and then letting it go, energy is released rapidly as the spring recoils. Examples of plyometric training include; squats, jumps, hops, push-ups, medicine ball throws, bounding, lunges to mention but few. Plyometric training should be implemented under supervision, since the technique and strength necessary to do the activities is broken by periods of rest to minimise injury.

d. **Isometric Training:** It is the application of force without joint movement. It means the muscles contract but there is no movement at the muscle or joint. For example, the wall sit exercise (stands with your back to a wall and bend the knees into a squat position and hold).

e. **Isotonic Training:** It means that the muscles contract and shorten to produce movement. It is the application of force to produce joint movement which can be adapted easily to suit different sports.

f. **Isokinetic Training:** The term isokinetic means moving at a constant rate of speed. A variable resistance isokinetic dynamometer is an electronic-mechanical instrument that maintains a constant speed of movement which varies the resistance during a particular movement.

6. **Endurance Training:** It is the act of exercising to increase endurance. The term endurance training generally refers to training the aerobic system as opposed to anaerobic. The following types of exercises are good for improving your cardiovascular endurance for example: road cycling, competitive swimming, rowing and cross country.

7. **Flexibility Training Method:** The range of movement is very important for athlete to be able to apply great force in a given movement. It also plays an important part in the development of all techniques. Where the athlete lacks that range, it must be developed through flexibility training. Although there are many ranges required. This makes the muscle to relax and as it does so, it is easier to increase the range of that joint.

Table 2: Example of a Training Method (Track & Field)

Training Methods for Track &Field	**Short Sprint**	**Long Sprint**	**Middle/Long Distance**	**Throws**	**Jumps**
Repetition Training	X	X	X	X	X
Anaerobic training (lactic)	X	X		X	X
Anaerobic (lactic)			X		
Circuit training (GF)	X	X			X
Circuit training (SE)		X	X		
Circuit training (PE)	X	X			X
Maximum strength	X	X			X
Explosive/Dynamic strength	X	X		X	X
Reactive strength	X	X		X	X
Flexibility training (PNF or static)	X	X	X	X	X

Principles of Training

Coaches need to train their athletes in order to improve performance using certain principles. It is called principles of training. According to Mackenzie (2000), the following are the principles of training that should be considered and used when designing a training programme:

1. **Progressive Loading** (“**Overload**”): Progressive overload is when an athlete performs a mobility exercise, he/she should stretch to the end of his/her range of movement. Improvement in mobility can only be achieved by working at beyond the active end position. A muscle can only strengthen when forced to operate beyond its customary intensity. Biological systems can adapt to loads that are higher than the demands of normal daily activity. Training loads must be increased gradually, however, to allow the body to adapt and to avoid injury (system failure due to overload). Varying the type, volume, and intensity of the training load allows the body an opportunity to recover, and to over-compensate. Loading must continue to increase incrementally as adaptation occurs, otherwise the training effect will plateau and further improvement will not occur.

2. **Adaptation**: Adaptation to the demands of training occurs gradually, over long period of time. Efforts to accelerate the process may lead to injury, illness, or "overtraining". Many adaptive changes reverse when training ceases. Conversely, an inadequate training load will not provide an adequate stimulus, and a compensatory response will not occur. Different training loads have different effects on the athlete's recovery. The body will react to the training loads imposed by increasing its ability to cope with those loads. Adaptation occurs during the recovery period after the training session is completed. Hawley (2008) stated that the time of adaptation may be quicker for high intensity sprint training when compared to low intensity endurance training, but that over a longer period, the two training regimes elicit similar adaptation.
3. **Specificity**: Energy pathways, enzyme systems, muscle fiber types, and neuro-muscular responses adapt specifically to the type of training to which they are subjected. For example, strength training has little effect on endurance. Conversely, endurance training activates aerobic pathways, with little effect on speed or strength. Even so, a well-rounded training programme should contain a variety of elements (aerobic, anaerobic, speed, strength, flexibility), and involve all of the major muscle groups in order to prevent imbalance and avoid injuries.
4. **Reversibility**: A regular training stimulus is required in order for adaptation to occur and to be maintained. Without suitable, repeated bouts of training, fitness levels remain low or regress to their pre-training level. Improved ranges of movement can be achieved and maintained by regular use of mobility exercises. If an athlete ceases mobility training his/her ranges of movement will decline over a period of time to those maintained by his/her other physical activities. When training ceases the training effect will also stop, it

eventually gradually reduces at approximately one third of the rate of acquisition narrated by Mseij (2013).

5. **Variation and Recovery**: Muscle groups adapt to a specific training stimulus in about three weeks and then plateau. Variations in training and periods of recovery are needed to continue progressive loading, without the risks of injury and /or overtraining. Training sessions should alternate between heavy, light, and moderate in order to permit recovery. The content of training programmes must also vary in order to prevent boredom and "staleness". Variation is especially important for plyometrics. Research in strength training shows that the muscular system responds best when the stimulus is varied over time (Coach Colleague, 2009)
6. **Individual Response**: Each athlete will respond differently to the same training stimulus. There are many factors that alter the training response: genetics, maturity, nutrition, prior training environment, sleep, rest, stress, illness or injury and motivation, to name a few. Some athletes may have a greater tolerance to training than the others, therefore individual programmes (Mseij, 2013).
7. **Periodisation of the Training Cycle:** Thompson and Levine (2006) reported that the training programme must consist of a variety of elements, including cardiorespiratory (aerobic) fitness, general strength, anaerobic fitness (power), speed, neuro-muscular skills development, flexibility, and mental preparation. The emphasis placed upon each of these elements must vary during the training year, but will also depend on the athlete's event and level of experience and maturity. Generally, basic preparation for all events should focus on general strength and aerobic fitness. Training cycles usually last about 3 weeks, with a week of lower-intensity recovery before starting the next cycle. Skills acquisition

should not be emphasised during a high-intensity training cycle, but should be reserved for periods of lower volume and intensity.

Cardiovascular Variables

Heart Rate

According to The American Heart Association (2015), heart rate, or heart pulse, is the speed of the heartbeat measured by the number of contractions of the heart per unit of time- typically beats per minute (bpm). The heart rate can vary according to the body's physical needs, including the need to absorb oxygen and excrete carbon dioxide. Activities that can provoke change include physical exercise, sleep, anxiety, stress, illness, ingesting and drugs.

The normal resting adult human heart rate ranges from 60-100 bpm. Tachycardia is a fast heart rate, defined as above 100 bpm. Bradycardia is a slow heart rate, defined as below 60 bpm at rest. During sleep, a slow heartbeat with rates around 40-50 bpm is common and is considered normal. When the heart is not beating in a regular pattern, this is referred to as an arrhythmia. These abnormalities of heart rate sometimes indicate disease.

Table 3: Heart rate abbreviations and their meanings

Abbreviation	**Meaning**
Bpm	beats per minute
HR	heart rate
THR	target heart rate
Hrmax	maximum heart rate
Hrrest	resting heart rate

Heart rate is not a stable value and it increases or decreases in response to the body's need in a way to maintain an equilibrium (basal metabolic rate) between requirement and delivery of oxygen and nutrients. The normal firing rate is affected by autonomic nervous system activity: sympathetic stimulation increases and parasympathetic stimulation decreases the firing rate. A number of different metrics are used to describe heart.

Resting Heart Rate

According to American Heart Association (2011), the basal or resting heart rate (HRrest) is defined as the rate when a person is awake, in a neutrally temperate environment, and has not undergone any recent exertion or stimulation, such as stress or surprise. The typical resting heart rate in adults is 60-100 beats per minute (bpm). For endurance athletes at the elite level, it is not unusual to have a resting heart rate between 33 and 50 bpm. This is the firing rate of the heart sinoatrial node, where the faster heart pacemaker cells driving the self-generated rhythmic firing and responsible for the cardiac muscle automaticity are located.

Target Heart Rate

For healthy people, the Target Heart Rate or Training Heart Rate (THR) is a desired range of heart rate reached during aerobic exercise which enables one's heart and lungs to receive the most benefit from a workout. This theoretical range varies based mostly on age; however, a person's physical condition, sex and previous training also are used in the calculation. Below are two ways to calculate one's THR. Klabunde (2005) reported that in each of these methods, there is an element called "intensity" which is expressed as a percentage. The THR can be calculated as a range of 65-85% intensity. However, it is crucial to derive an accurate HRmax to ensure these calculations are meaningful.

Example for someone with a HRmax of 180 (age40, estimating HRmax AS 220-age):

65% Intensity: (220-(age= 40)) X 0.65 → 117 bpm

85% Intensity: (220- (age= 40)) X 0.85→ 153 bpm

Karvoven Method

The Karvonen method factors in resting heart rate (HRrest) to calculate target heart rate (THR), using a range of 50-85% intensity.

THR= (HRmax− HRrest) X % intensity) +HRrest

Example for someone with a HRmax of 180 and a HRrest of 70:

50% Intensity: ((180− 70) × 0.50) + 70= 125 bpm

85% Intensity: ((180−70)× 0.85) + 70= 163 bpm

Zoladz Method

An alternative to the Karvonen method is the Zoladz method, which derives exercise zones by subtracting values from HRmax:

THR= HRmax– Adjuster ± 5 bpm

Zone 1 Adjuster = 50 bpm

Zone 2 Adjuster = 40 bpm

Zone 3 Adjuster = 30 bpm

Zone 4 Adjuster = 20 bpm

Zone 5 Adjuster = 10 bpm

Example for someone with a HRmax of 180:

Zone 1 (easy exercise): 180 −50 ±5 →125- 135 bpm

Zone 4 (tough exercise): 180 −20±5→ 155-165 bpm

Maximum Heart Rate

According to American Heart Association (2015), the maximum heart rate (HRmax) is the highest heart rate an individual can achieve without severe problems through exercise stress, and generally decreases with age. Since HRmax varies by individual, the most accurate way of measuring any single person's HRmax is via a cardiac stress test. In this test, a person is subjected to controlled physiologic stress (generally by treadmill) while being monitored by an ECG. The intensity of exercise is periodically increased until certain changes in the heart function are detected on the ECG monitor, at which point the subject is directed to stop. Typical duration of the test ranges ten to twenty minutes.

Adults who are beginning a new exercise regimen are often advised to perform this test only in the presence of medical staff due to risks associated with high heart rates. For general purposes, a formula is often employed to estimate a person's maximum heart rate. However, there were predictive formulas that have been criticised as inaccurate because they generalised population-averages and usually focus on a person's age. It is well-established that there are a "poor relationship between maximal heart rate and age" and large standard deviations around predicted heart rates. A 2002 study of 43 different formulas for HR published in the Journal of Exercise Physiology (ACSM, 2009) concluded that:

1. No "acceptable" formula currently existed (they used the term acceptable to mean acceptable for both prediction of Vo_2max, and prescription of exercise training HR ranges).
2. The least objectionable formula was:

   HRmax= 205.8- (0.685 x age). This had a standard deviation that, although large (6.4 bpm), was considered acceptable for prescribing exercise training HR ranges.

Limitations of Heart Rate

Maximum heart rates vary significantly between individuals. Even within single elite sports team, such as Olympic rowers in their 20s; maximum heart rates have been reported as varying from 160-220 bpm. According to Wilson and Costill (2005), a variation would equate to a 60 or 90 year age gap in the linear equations above, for example would seem to indicate the extreme variation about these average figures. Figures are generally considered averages, and depend greatly on individual physiology and fitness. For example, an endurance runner's rates will typically be lower due to the increased size of the heart required to support the exercise, while a sprinter's rates will be higher due to the improved response time and short duration. While each may have predicated heart rates of 180 (= 220-age), these two people could have actual HRmax 20 beats apart (e.g., 170- 190).

Further, note that individuals of the same age, the same training, in the same sport, on the same team, can have HRmax 60 bpm range (160-220): the range is extremely broad and some were of the opinion that the heart rate is probably the least important variable in comparing athletes.

Blood Pressure

Blood pressure is the pressure of the blood in the circulatory system, often measured for diagnosis since it is closely related to the force and rate of the heartbeat and the diameter and elasticity of the arterial walls (Robert, 2012). Blood pressure is typically recorded as two numbers. Read as "117 over 76 millimeters of mercury".

Systolic- The top number, which is also the higher of the two numbers, measures the pressure in the arteries when the heart beats (when the heart muscle contracts).

Diastolic- The bottom number, which is also the lower of the two numbers, measures the pressure in the arteries between heartbeats (when the heart muscle is resting between beats and refilling with blood).

American Heart Association (2015) explained that blood pressure is the pressure exerted by circulating blood upon the walls of blood vessels. When used without further specification, "blood pressure" usually refers to the arterial pressure in the systemic circulation. It is usually measured at the upper arm. Blood pressure is usually expressed in terms of the systolic (maximum) pressure over diastolic (minimum) pressure and is measured in millimeters of mercury (mmHg). It is one of the vital signs along with respiratory rate, heart rate, oxygen saturation, and blood temperature. Normal resting blood pressure in an adult is approximately 120/80 mmHg. Blood pressure varies depending on situation, activity and stages of disease. It is regulated by the nervous and endocrine systems. Blood pressure that is low due to a state of disease is called hypotension, and pressure that is consistently high is hypertension. Both have many causes which can range from mild to severe. Both may be of sudden onset or of long duration. Long term hypertension is a risk factor for many diseases, including kidney failure, heart disease and stroke. Long term hypertension is more common than long term hypotension in Western countries. Long term hypertension often goes undetected because of infrequent monitoring and the absence of symptoms.

This chart reflects blood pressure categories defined by the American Heart Association (2015).

Normal: Systolic is less than 120 mmHg and Diastolic is less than 80 mmHg

Prehypertension: Systolic is 120-139 mmHg or Diastolic is 80- 89 mmHg

Hypertension Stage 1: Systolic is 140-159 mmHg or Diastolic is 90-99 mmHg

Hypertension Stage 2: Systolic is 160mmHg or higher or Diastolic is 100 mmHg or higher

Hypertensive Crisis (**Emergency care needed**): Systolic is higher than 180 mmHg or Diastolic is higher than 110 mmHg

Mean Arterial Pressure (MAP)

According to American Heart Association (2014), mean arterial pressure (MAP) is considered to be the perfusion pressure seen by organs in the body. It is considered a better indicator of perfusion to vital organs than systolic blood pressure (SBP). True MAP can only be determined by invasive monitoring and complex calculations; however it can also be calculated using a formula of the SBP and the diastolic blood pressure (DBP).

To calculate a mean arterial pressure, double the diastolic blood pressure and add the sum to the systolic blood pressure. Then divide by 3. For example, if a patient's blood pressure is 83mmHg/50 mmHg, his MAP would be 61 mmHg. Here are the steps for this calculation:

$$MAP = \frac{SBP + 2\,(DBP)}{3}$$

$$MAP = \frac{83 + 2\,(50)}{3}$$

$$MAP = \frac{83 + 100}{3}$$

$$MAP = \frac{183}{3}$$

MAP = 61 mmHg

Another way to calculate the MAP is to first calculate the pulse pressure (subtract the DBP from the SBP) and divide by 3, then add the DBP:

MAP = 1/3(SBP- DBP) + 50

MAP = 1/3 (83-50) + 50

MAP = (33) + 50

MAP = 11 + 50

MAP = 61 mmHg

There are several clinical situations in which it is especially important to monitor mean arterial pressure. In patients with sepsis, vasopressors are often titrated based on the MAP. In that situation, it is recommended that mean arterial pressure (MAP) be maintained ≥65 mmHg. Also, in patients with head injury or stroke, treatment may be dependent on the patients MAP.

Wilmore and Costill (2005) opined that a MAP that is greater than 60 mmHg is enough to sustain the organs of the average person. MAP is normally between 70-110 mmHg. When the MAP falls below this number for an appreciable time, vital organs will not have enough oxygen perfusion, a condition called arrhythmias. The mean arterial pressure can also be determined by the cardiac output (CO), systemic venous pressure resistance (SVR), and central venous pressure (CVP) according to the following relationship, which is based upon the relationship between flow, pressure and resistance. MAP = (CO × SVP) + CVP, because CVP is usually at or near 0mmHg, this relationship is often simplified to: MAP approx. =CO ×SVR

Therefore, changes in either CO or SVR will affect MAP. If CO and SVR change reciprocally and proportionately, then MAP will not change (AHA, 2014). For example, if CO doubles and SVR decreases by one-half, MAP does not change (if CVP=0). It is important to note that variables found in equation 1 are all interdependent. This means that changing one variable changes all of the others.

Cardiovascular Response to Aerobic Exercise

All types of human movement, no matter what the mode, duration, intensity or pattern, require an expenditure of energy above resting values. Much of this energy will be provided through the use of oxygen (ACSM, 2009). Aerobic exercise requires more energy and, hence, more oxygen (and thus of the term aerobic, with oxygen) than either static or dynamic resistance exercise. How much oxygen is needed depends primarily on the intensity at which the activity is performed and secondarily on the duration of the activity.

Short-Term, Light to Moderate Sub-Maximal Aerobic Exercise

According to Robert (2012), at the onset of short-term, light to moderate intensity exercise, there is an initial increase in cardiac output (Q) to a plateau at steady state. Cardiac output plateaus within the first two minutes of exercise, reflecting the fact that cardiac output is sufficient to transport the oxygen needed to support the metabolic demands (ATP production) of the activity. Cardiac output increases due to an initial increase in both stroke volume (SV) and heart rate (HR). Both variables level off within two minutes. During exercise of this intensity the cardiorespiratory system is able to meet the metabolic demands of the body. Thus, the term **steady state** or steady rate is often used to describe this type of exercise. Patel (2014) affirmed that during steady state exercise, the exercise is performed at intensity such that energy expenditure is balanced with the energy required to perform the exercise. The plateau evidenced by the cardiovascular variables indicates that a steady state has been achieved.

The increase in stroke volume results from an increase in venous return, which in turn, increases the left ventricular end-diastolic volume (LVEDV) preload. According to American Heart Association (2011), the increased preload stretches the myocardium and causes it to contract more forcibly in accordance with the Frank-Starling law of the heart. Contractility of the myocardium is also enhanced by the sympathetic nervous system, which is activated during physical activity. Thus, an increase in the left ventricular end-diastolic volume and a decrease in the left ventricular end-systolic volume (LVESV) account for the increase in stroke volume during light to moderate dynamic exercise. Hrysomallis (2012) added that Heart rate increases immediately at the onset of activity as a result of parasympathetic withdrawal. As exercise continues, further increases in heart rate are due to the action of the sympathetic nervous system.

Systolic blood pressure (SBP) will rise in a pattern similar to that of cardiac output, there is an initial increase and a plateau once steady state is achieved. The increase in systolic blood pressure is brought about by the increase in cardiac output. Systolic blood pressure would be even higher if not the fact that resistance decreases, thereby partially offsetting the increase in cardiac output. Steinbaum (2014) expressed that when blood pressure (BP) is measured intra-arterially, diastolic blood pressure (DBP) does not change. When it is measured by auscultation it either does not change or may go down slightly. Diastolic blood pressure remains relatively constant because of peripheral vasodilation, which facilities blood flow to the working muscles. The small rise in systolic blood pressure and the lack of a significant change in diastolic blood pressure cause the mean arterial pressure (MAP) to rise only slightly, following the pattern of systolic blood pressure.

Cardiovascular Response to Dynamic Resistance Exercise

Weight –lifting or resistance exercises includes a combination of dynamic and static contractions (Hill, 1970). At the beginning of the lift, a static contraction exists until muscle force exceeds the load to be lifted and movement occurs, which leads to a dynamic concentric (shortening) contraction as the lift continues. This is followed by a dynamic eccentric (lengthening) contraction during the lowering phase. Furthermore, Chu (2004) explained that there is always a static component associated with gripping the barbell. During dynamic resistance exercise there is dissociation between the energy demand and the cardio-respiratory system. In contrast, during endurance activity the cardiorespiratory system is directly tied to the use of oxygen for energy production. In fact, the reason for this dissociation between oxygen use and cardiovascular response to resistance exercise is that much of the energy required for resistance exercise comes from anaerobic (without oxygen) sources (Sankarmani, et al., 2012). Another important difference between resistance exercise and aerobic exercise that affects cardiovascular responses is the mechanical constriction of blood flow during resistance exercise because of the static nature of the contraction. The magnitude of the cardiovascular response to resistance exercise depends on the intensity of the load (the weight lifted) and the number of repetitions performed.

Constant Repetitions/Varying Load

The cardiovascular responses also depend on the way in which the load and repetitions are combined. As expected, cardiovascular responses are greater when heavier loads are lifted, assuming the number of repetitions is held constant (Fleck & Kraemer, 2004). For example, when subjects performed ten repetitions of three different weights (identified as light, moderate and heavy), blood pressure was highest at the completion of the heaviest set. Systolic blood pressure increased 16%, 22%, and 34% during the light, moderate and heavy sets respectively. Diastolic blood pressure, measured by auscultation, did not change significantly with any of the sets. There is disagreement about the diastolic blood pressure response to resistance exercise; some authors report an increase and others report no change. Chaudhary, Manpreet and Sandhu (2010) noted that these discrepancies may reflect differences in measurement techniques (namely; auscultation and intra-arterial assessment) and timing of the measurement.

Cardiovascular Variables and Response to Exercises: Position Stand

The cardiovascular variables that respond to exercises according to American College of Sports Medicine (2009) under position stand are the following:

1. During short–term, light to moderate aerobic exercise, cardiac output, stroke volume, heart rate, systolic blood pressure and rate pressure product increase rapidly at the onset of exercise and reach steady state within approximately 2 minutes. Diastolic blood pressure remains relatively unchanged, and resistance decreases rapidly and then plateaus.
2. During long-term, moderate to heavy aerobic exercise, cardiac output, stroke volume, heart rate, systolic blood pressure, and rate pressure product increase rapidly. Once steady state

is achieved, cardiac output remains relatively constant owing to the downward drift of stroke volume and upward drift of heart rate. Systolic blood pressure and resistance may also drift downward during prolonged, heavy work. This cardiovascular drift is associated with rising body temperature.

3. During incremental exercise to maximum, cardiac output, heart rate, systolic blood pressure, and rate pressure product increase in a rectilinear fashion with increasing workload. Stroke volume increases initially and then plateaus at a workload corresponding to approximately 40-50% of VO_2max in normally active adults and children. Diastolic blood pressure remains relatively constant throughout an incremental exercise test. Resistance decreases rapidly with the onset of exercise and reaches its lowest value at maximal exercise.
4. The decrease in resistance that accompanies aerobic exercise has two important implications. First, the decrease in resistance allows greater blood flow to the working muscles. Second, the decrease in resistance keeps blood pressure from rising excessively. The increase in cardiac output would produce a much greater rise in blood pressure if it were not for the fact that there is a simultaneous decrease in resistance.
5. Blood volume decreases during aerobic exercise. The majority of the decrease occurs within the first 10 minute of activity and depends on exercise intensity. A decrease of 10% of blood volume is not uncommon.
6. Stroke volume initially increases during dynamic aerobic exercise and then plateaus at a level that corresponds to 40-50% of Vo_2max. The increase in stroke volume results from changes in left ventricular end-diastolic volume and left ventricular end –systolic volume. Left ventricular end- diastolic volume increases primarily because the active muscle pump returns blood to the heart. Left ventricular end-systolic volume decreases owing to

augmented contractility of the heart, thus ejecting more blood and leaving less in the ventricle.

7. The pattern of cardiovascular response is the same for both sexes. However, males have a higher cardiac output, stroke volume, and systolic blood pressure at maximal exercise. Additionally, males have a higher Vo_2max. Most of these differences are attributable to differences in body size and heart size between the sexes and to the greater hemoglobin concentration of males.
8. The pattern of cardiovascular response in children is similar to the adult response. However, children have a lower cardiac output, stroke volume, and systolic blood pressure at an absolute workload and at maximal exercise. Most of these differences are attributable to differences in body size and heart size.
9. As adult age, their cardiovascular responses change. Maximal cardiac output, stroke volume, heart rate, and Vo_2max decrease. Maximal systolic blood pressure, diastolic blood pressure, and mean arterial pressure increase.
10. Static exercise is characterised by modest increases in heart rate and cardiac output and exaggerated increases in systolic blood pressure, diastolic blood pressure and mean arterial pressure, known as the presser response.
11. Dynamic resistance exercise results in a modest increase in cardiac output, an increase in heart rate, little change or a decrease in stroke volume, and a large increase in blood pressure.

The Electrocardiogram (ECG)

The Electrocardiogram (also known as an ECG or EKG) is a medical test that detects cardiac (heart) abnormalities by measuring the electrical activity generated by the heart as it contracts (The Victoria State Government, 2015). The ECG can help diagnose a range of conditions including heart arrhythmias, heart enlargement, heart inflammation and coronary heart disease. The ECG is widely used today either in the clinical evaluation of patients with cardiovascular diseases or as part of the routine examination of selected groups of patients or healthy subjects. The ECG produces a distinctive waveform in response to the electrical changes taking place within the heart.

The first part of the wave, called the P wave, is a small increase in voltage of about 0.1mV that corresponds to the depolarisation of the atria during atrial systole. The next part of the ECG wave is the QRS complex which features a small drop in voltage (Q) a larger voltage peak (R) and another small drop in voltage (S). The QRS complex corresponds to the contraction of the ventricles during ventricular systole. The atria also relax during the QRS complex, but have almost no effect on the ECG because they are so much smaller than the ventricles.

The final part of the ECG wave is the T wave, a small peak that follows the QRS complex. The T wave represents the ventricular recovery during the relaxation phase of the cardiac cycle. Variations in the wave form and distance between the waves of the ECG can be used clinically to diagnose the effects of heart attacks, congenital heart problems, and electrolyte imbalances.

Heart Problems Diagnosed by ECG

Some of the various heart problems that can be diagnosed by ECG according to WHO (1981) include:

a. Enlargement of the heart

b. Congenital heart defects involving the conducting (electrical) system

c. Abnormal rhythm (arrhythmia)- rapid, slow or irregular heart beats

d. Damage to the heart such as when one of the heart’s arteries is blocked (coronary occlusion)

e. Poor blood supply to the heart

f. Abnormal position of the heart

g. Heart inflammation- pericarditis or myocarditis

h. Cardiac arrest during emergency room or intensive care monitoring

i. Disturbances of the heart's conducting system

j. Imbalances in the blood chemicals (electrolytes) that control heart activity.

A person with heart disease may have a normal ECG result if the condition does not cause a disturbance in the electrical activity of the heart. Other diagnostic methods may be recommended if heart disease is suspected.

Medical Issues to Consider with an ECG

Luttgens and Hamilton (1997) explained that a doctor may recommend an ECG if a patient is experiencing symptoms such as chest pain, shortness of breath, dizziness, fainting, or fast or irregular heartbeats (palpitations). ECGs are often performed to monitor the health of patients who have been diagnosed with heart problems, to help assess artificial cardiac pacemakers or to monitor the effects of certain medications on the heart. There is no need to restrict food or drink prior to the test. You should always let your doctor know what medications you are taking before you have an ECG, and if you have any allergies to adhesive tapes that may be used to attach electrodes.

ECG Procedure

You strip to the waist so that electrodes can be attached to your chest and limbs. Women should consider wearing a separate top to their trousers or skirt to allow easy access to the chest. The selected sites are shaved, if necessary. Sensors called electrodes are attached to the chest, arms and legs. With either suction cups or sticky gel. These electrodes detect the electrical currents generated by the heart that are measured and recorded by the electrocardiogram machine.

According to World Health Organization (1981), the three major types of ECG include:

1. **Resting ECG**: The patient lies down. No movement is allowed during this time, as electrical impulses generated by other muscles may interfere with those generated by your heart. This type of ECG usually takes five to 10 minutes.
2. **Ambulatory ECG**: Ambulatory or Holter ECG is performed using a portable recording device that is worn for at least 24 hours. The patient is free to move around normally while the monitor is attached. This type of ECG is used for patients whose symptoms are intermittent and may not appear during a resting ECG. People recovering from heart attack may be monitored in this way to ensure proper heart function. The patient usually records symptoms in a diary, noting the time so that their own experience can be compared with the ECG.
3. **Cardiac Stress Test**: This test is used to record a patient's ECG while the patient rides on an exercise bike or walks on a treadmill. This type of ECG takes about 15 to 30 minutes to complete.

General Applications and Uses of the ECG

The diagnostic information from the ECG can be divided into three categories (WHO, 1981):

1. Identification of cardiac rhythm and conduction disturbances which are primarily defined and detected by the ECG itself.
2. Diagnosis of certain anatomical conditions and aspects of myocardial function which can be diagnosed on the basis of ECG findings with some probability of success. This category includes ECG findings of myocardial infarction, injury and ischaemia, as well as ventricular and atrial hypertrophy or enlargement and furthermore, ECG findings related to pulmonary disease and certain metabolic changes or drug effects.
3. ECG abnormalities which may or may not be related to anatomical or physiological cardiac abnormalities. ECG findings of this category include axis deviation, QRS voltage

abnormalities and non-specific ST- T abnormalities. These findings may have importance in the context of other clinical information.

The ECG was originally introduced for the diagnosis of cardiovascular conditions and that is still the most importance application of the technique. However, Jenny (2012) expressed that with technical progress, ECG recording has become an easy and readily available procedure, now widely used as part of the routine examination of patients who are primarily seen because of other conditions. A review of the situation showed that in the European countries almost one-half of ECGs recorded in general hospitals are taken in non-cardiac patients. Furthermore, the use of the ECG in check-ups of health people has been increasing.

The Diagnosis and follow-up of cardiovascular conditions

Cardiac Arrhythmias

The ECG has a central and established role in the diagnosis and follow-up of various types of cardiac arrhythmias. The conventional resting ECG is useful in the diagnosis of chronic forms of arrhythmias. The detection and diagnosis of transient or paroxysmal arrhythmias requires continuous monitoring, as carried out in coronary care units or in the ambulatory 24-hour recording by portable tape recorders. The same concepts apply to the diagnosis of cardiac arrhythmias or conduction disturbances can be obtained by intra-cardial ECG recordings in specialised cardiological centres.

Ischaemic Heart Disease

The ECG makes, in addition to clinical and laboratory findings, an essential contribution to the diagnosis of acute myocardial infarction. Klabunde (2005) added that in most instances serial ECGs taken on consecutive days after the onset of symptoms provide a correct diagnosis. Sometimes diagnostic ECG changes develop more slowly and sometimes they may be obscured by other ECG abnormalities, like intraventricular conduction disturbances. After recovery from acute myocardial infarction QRS abnormalities often diminish or disappear and therefore the diagnosis of an old myocardial infarction cannot always be made on the basis of the resting ECG. In some instances full cancellation of QRS abnormalities occurs after a new myocardial infarction.

According to WHO (1981), instable angina pectoris, the resting ECG may remain normal for years. Therefore, exercise stress testing is often needed in the diagnosis of myocardial ischaemia. In the follow-up of patients who have survived a myocardial infarction, patients with angina pectoris or patients who have been subjected to bypass surgery, a resting ECG and, if needed, ECG recordings in connection with exercise stress testing, should be taken only as part of a complete clinical evaluation.

ECG recording is nowadays readily available for the diagnosis of acute myocardial infarction, even in small hospitals, or the patient’s home. The problems in utilisation of diagnostic information from the ECG, however, are usually greatest in these circumstances. Adequate training of general practitioners in the essential features of ECG diagnosis of acute myocardial infarction is very important. Furthermore, a regional ECG consultation service may be needed in cases of diagnostic difficulty.

Jenny (2012) affirmed that exercise stress testing, including an exercise ECG, requires good facilities, much expertise and should be confined to regional cardiology centres or laboratories which can provide not only exercise stress testing, but also a full clinical evaluation of the patient. The capacity for exercise stress testing is below the need in many European countries due to the quality requirements.

Hypertension

American Heart Association (2011) expressed that ECG recording is part of the basic diagnostic work-up and follow-up of hypertensive patients. The frequency at which it must be done in the follow-up depends on the severity of hypertension, symptoms and the type of therapy. There may be a trend to overuse of the ECG in the follow-up of mildly hypertensive patients from the point of view of the information which can be expected from sequential ECGs. Information concerning the use of the ECG in the routine follow-up of hypertensive patients may be obtained from the WHO-coordinated programmes for community control of hypertension.

Other Cardiac Diseases

The ECG is used in both the diagnosis and follow-up of patients with congenital heart diseases, acquired valvular diseases, cardiomyopathies or inflammatory cardiac diseases, since in these instances ECG is always part of the overall evaluation of the patient.

Routine Examination of Non-Cardiac Patients

According to WHO (1981), an ECG is nowadays taken as part of the routine examination of many groups of non-cardiac patients. In virtually all European countries, this applies to all patients admitted to departments of internal medicine, while elsewhere the procedure is routine for virtually all adult patients admitted to general hospitals. In some countries ECG recording is routine for all patients who will undergo general anaesthesia, and in others for pregnant women. On the other hand, the practice of taking a preoperative ECG may vary between hospitals.

Health Check-Ups

The ECG is used in health check-ups in certain circumstances, in most of which the justification is not based on any hard medical data. Such circumstances, which vary from country to country, according to WHO (1981) include:

1. Initial health examinations and regular follow-up examinations of occupational groups in mass transport, such as airline pilots.
2. Health examinations of employees in state offices, international organizations, industrial enterprises, etc.
3. Medical examinations for life insurance.

Health check-ups or screening examinations of middle-aged people, particularly men who are supposed to be at increased risk of ischaemic heart disease.

Special Uses/Application of the ECG

World Health Organization (1981) further added that this special use of the ECG allows detection of dynamic changes in the rate, rhythm, conduction and ventricular repolarisation, as manifested by S-T and T wave abnormalities. The procedure can be performed in the hospital by means of a bedside recorder, telemeter (in progressive care units or rehabilitation programmes) or portable tape recorder (Holter monitoring). Portable recorders are also used for continuous monitoring of ambulatory patients outside the hospital.

Inpatients

American Heart Association (2014) stated that Continuous ECG monitoring in the hospital is a standard practice in patients at high risk of developing lethal arrhythmias, such as those with acute myocardial infarction, major conduction defects or digitalis intoxication, or those who have undergone cardiac surgery or another major operation. Continuous ECG monitoring provides the basis for proper coronary care. In most of the coronary care units visited, detection, diagnosis and quantification of arrhythmias are based on human surveillance of continuous recording and on simple alarms triggered by rate changes. WHO (1981) added that this approach fails to detect transient arrhythmias in a relevant percentage of cases. Some computer programmes have been developed and are in use in a minority of centres. It is felt however, that automatic arrhythmia detection and diagnosis need further validation as to accuracy and reliability.

Outpatients

Continuous outpatient monitoring is important in assessing paroxysmal arrhythmias or conduction defects in patients with daily or frequent, rather than occasional symptoms (WHO, 1981). A careful clinical evaluation to identify non-cardiac causes of these symptoms should be carried out in all cases. Continuous monitoring may be useful to detect and control arrhythmias in patients after myocardial infarction in order to reduce the danger of sudden death. It also is important in assessing the efficacy of treatment in selected patients with symptomatic arrhythmias and in evaluating asymptomatic patients for conduction defects. American Heart Association (2014) added that because S-T and T changes observed during continuous ambulatory monitoring are not reliable indicators of myocardial ischaemia and can be observed in subjects with no heart disease, continuous monitoring should not be used for routine evaluation of patients with angina and is therefore not a substitute for exercise testing.

Technical Aspects

Resting ECGs

The American Heart Association (2015) issued the recommendations that cover the currently available performance requirements of single-and-multichannel ECG recorders for conventional ECG recording. Direct writing ECG instruments are used throughout Europe. Single channel recorders are still widely used, not only as portable or emergency instruments, but also for routine work. The use of multi-channel recorders which have the advantage of more efficient recording and easier, more reliable interpretation is increasing, but has so far not become as common as it ought to be in laboratories recording large numbers of ECGs. More sophisticated automatic multi-channel recorders are being introduced, mostly in connection with computer aided system. The performance characteristics of the various types of recorder vary widely and do not always meet the technical requirements defined by the above mentioned bodies. Moreover, periodic checking of the performance of ECG equipment is often neglected.

Recording Technique of ECG

Robert (2012) explained that the conventional 12 leads are used throughout Europe, although additional leads are still used in some countries. In the majority of countries 25mm paper speed is used in the recording, although in the Scandinavian and the German-speaking countries 50mm paper speed is in use. The technical skill of the personnel recording ECGs seems to leave much to be desired. Useful recommendations concerning the requirements and form of training for ECG technicians have been given. Continuous quality control requires the performance of the recording instruments is continuously checked, as mentioned above. At the same time the performance of ECG technicians must be continuously checked by the physician or cardiologist responsible for ECG interpretation. For effective feedback, the identification of the technician should be given on each ECG tracing.

Interpretation and Reporting

American Heart Association (2011) narrated that throughout and within the European countries a great variation has been observed in the ways of analysing and reporting ECGs. Some hospitals or laboratories give a full description of the ECG record, measuring all parameters and making a synthetic report, while others give only summary statements and some include only brief comments on the ECG in the consultation report or in the patient’s medical record. It appears to be not uncommon, even in hospitals, for formal reporting on ECG findings to be completely omitted.

Empirical Studies

The empirical studies for this study were discussed under the two following subheadings:

a. Plyometric training and the improvement of sports performance
b. Effects of plyometric/strength training on cardiovascular variables

Plyometric Training and the Improvement of Sports Performance

Several studies have been conducted by many researchers in the use of plyometric training and improvement of sports performance.

Papadakis and Grandjean (2015) researched on the influence of plyometric training volume varied by exercise sets on lower-body explosive power. Seventy-two recreational exercisers participated in the study. The study adopted a true experimental research design in which the subjects were randomly assigned to one of three groups: two-set, four-set or non-plyometric control group. The Control group exercised *ad libitum* with the exception of any plyometric exercise. Training by experimental groups included weighted static jumps (SJ) and countermovement jumps (CMJ) using heavy and light loads, under a supervised and periodized programme for three days a week over eight weeks. Heavy loads were ramped up by 10% of one-repetition maximum (1RM) each week starting from 60% of 1RM, followed by a light load of 30% of 1RM for eight repetitions for the first four weeks of training. During the last four weeks, the heavy loads were ramped down by 10% of 1RM each week starting from90% of 1RM. The executed repetitions for the heavy loads for each week and each work-out day were periodized from four to fifty repetitions. The dependent variables were vertical jump height (H) and power (PW) of SJ and CMJ. One-way analysis of variance with paired post-hoc analysis on mean post-pre differences were employed to determine significant effects ($p<0.05$). Improvement in SJ –H ($p=0.0099$), SJ-PW ($p=0.0208$), CMJ-H ($P=0.0037$), CMJ-PW ($P=0.0037$) were all greater in 4-set group when compared to two-set and control group. The two-set group did not differ from the control in any of the dependent variables. The results show that plyometric training does not always improve explosive power.

Papadakis and Grandjean's study is similar to the present study in that both studies focused on plyometric training on healthy individuals using three groups. However, the present study focused on male athletes only. It however differed in population, method of analysis and the intervening variables which are cardiovascular variables and ECG. In addition, the present study was a quasi-experimental while Papadaki and Grandjean's study used a true experimental research design.

Chelly (2014) conducted a study on the effects of an eight- biweekly programme of plyometric training using squat and countermovement in twenty-three top-level adolescent handball players. The study was a true experimental research design in which the subjects were randomly divided into two groups; an experimental or control group. After eight-biweekly programme of plyometrics using squat and countermovement average power output of leg muscle were collected. Data were analysed using percentages to answer the research questions and ANOVA to test the hypotheses. The researchers found that the plyometric training group improved countermovement jump power as well as leg muscle volumes relative to control group. Chelly's study is similar to the present study in that both studies are focused on plyometric training, athletes with the same population and in method of data analysis but differed in the intervening variables which are cardiovascular variables and ECG.

Ramirez-Campillo, Andrade, Alvarez, Henriquez-Olguin, Martinez, Baez-SanMartin, Silva-Urra, Burgos and Izquierdo (2014) carried out a study on the effects of plyometric training using 30, 60, or 120 of rest between sets on explosive adaptations in young soccer players. The study adopted a true- experimental research design that lasted for seven weeks. Fifty-four soccer players participated and were randomly assigned into four groups: control (CG; n=15), plyometric training with 30 s (G 30; n=13), 60 s (G 60; n=14), and 120 s (G 120; n=12) of rest between training sets. Before and after intervention players were measured in jump ability, 20 minutes sprint time, change of direction speed (CODS), and kicking performance. The training programme was applied during seven weeks, two sessions per week, for a total of 840 jumps. To determine the effect of intervention on performance adaptations, a 2-way variance analysis with repeated measures was applied. When a significant F-value was achieved across time or between groups, Tukey post hoc procedures were performed to locate the pair wise differences between the means. After intervention the G 30, G 60 and G 120 groups showed a significant (p=0.0001-0.0.04) and small to moderate effect size (ES) improvement in the countermovement jump (ES=0.49; 0.58, 0.55), 20 cm drop jump reactive strength index (ES=0.81; 0.89; 0.86), CODS (ES= -1.03; -0.87; -1.04), and kicking performance (ES= 0.39; 0.49; 0.43), with no differences between treatments. The study shows that 30, 60, and 120 s of rest between sets ensure similar significant and small to moderate ES improvement in jump, CODS, and kicking performance during high-intensity short-term explosive training in young male soccer players. The above study is related to the present study in that both used plyometric training on young athletes but differs in population, method of data analysis and in the assessment of cardiovascular variables and ECG.

Arazi and Asadi (2011) assessed the effects of aquatic and land plyometric training on strength, sprint and balance in young basketball players in Iran. The Authors used a true experimental research design. Eighteen volunteered young male basketball players participated and were randomly assigned to three groups; aquatic plyometric training group (APT), land plyometric training group (LPT) and control group (CON). Experimental groups trained on; ankle jumps, speed marching, squat jumps, and skipping drills for eight weeks and three times a week for 40 minutes. The data were analysed with independent-sample t-test, one way analysis of variance and Turkey post hoc testing. The results showed that there were no significant differences between the APT and LPT groups in any of the variables tested ($p>0.05$). Significant increase were observed in post-training both APT and LPT groups in 36 minutes and 60 minutes sprint times record compare to pre-training ($p<0.05$).There was a significant difference in relative improvement between the APT and CON in 36 minutes, 60 minutes and one repetition maximum leg press ($p<0.05$). The researchers concluded that plyometric training in water can be an effective technique to improve sprint and strength in young athletes. Arazi and Asadi's study is similar to the present study in that both studies focused on plyometric training and young athletes but differed in the intervening variables which are effect on cardiovascular variables and ECG.

Thomas, French and Hayes (2009) conducted a study on the effect of two plyometric training techniques on muscular power and agility in United Kingdom. It was a true experimental research design in which twelve male soccer players participated. The study lasted for six weeks and subjects were randomly assigned to six weeks of depth jump (DJ) or countermovement jump (CMJ) training twice weekly. Participants in the DJ group performed drop jumps with instructions to minimise ground-contact time while maximising height. Participants in the CMJ group performed jumps from a standing start position with instructions to gain maximum jump height. The data were analysed using t-test paired statistics. Post training, both groups experienced improvements in vertical jump height ($p<0.05$) and agility time ($p<0.05$) and no change in sprint performance ($p>0.05$). There were no differences between the treatment groups ($p>0.05$). The study concluded that both DJ and CMJ plyometrics were worthwhile training activities for improving power and agility in youth soccer players.

Thomas, et al.'s study is similar to the present study in that two plyometric training techniques were used for athletes but differ in population, method of data analysis, duration of the study and the intervening variables- cardiovascular which is the focus of this study and ECG.

Ronnestad, Kvamme, Sunde and Raastad (2008) assessed the effects of plyometric training on power output in fourteen professional soccer players over a seven-week intervention. The study adopted a true experimental research design in which the subjects were randomly divided into two groups. One group performed a plyometric training programme twice a week as well as six-eight week soccer sessions per week. A control group performed six-eight soccer sessions per week. The data were collated and analysed using mean, standard deviation and t-test. The researcher measured peak power in the half squat with 20kg, 35kg, and 50kg before and after the intervention. The researcher found that the training group significantly improved peak power in the half squat with 20kg, 35kg, and 50kg but the control group only improved peak power with 20kg. Ronnestad, et al's study is similar to the present study in that both used athletes with plyometric training over a seven-week intervention and method of data analysis. However, the area of difference is that while Ronnestad, et al used true experimental research design, the present study used quasi experimental research design. It also differs in population and intervening variables which is cardiovascular variables and ECG.

In another study by Milic, Nejic and Kostic (2008) on the effect of plyometric training on the explosive strength of leg muscles of volleyball players on single foot and two-foot take-off jumps. The study lasted for six weeks plyometric training programme in which forty-six volleyball players aged 16 years participated. It was a true experimental research design. The subjects were randomly divided into two groups; experimental (n=23) and control group (n=23) who had not been exposed to the plyometric method as part of their physical education classes.

The sample of measuring instruments consisted of eight tests of explosive leg strength: the two-foot takeoff block jump, the right foot takeoff block jump, the left foot take-off block jump, the two-foot takeoff spike jump, the right foot takeoff spike jump, the left foot takeoff spike jump, the standing depth jump and the standing triple jump. A multivariate and univariate statistical method was used to determine a statistically significant difference in explosive strength in four of the experimental group. The researchers found out that there was an increase in explosive strength for the two-foot and single foot takeoff jumps. Both studies were experimental using plyometric training on athletes but differ in methods, population and the intervening variables which are cardiovascular variables and ECG.

In an attempt to present a four-week plyometric training programme, Markovic (2007) used Meta-analyses of randomised and non-randomised controlled trials that evaluated the effect of PT on four typical vertical jump height tests were used; squat jump (SJ),countermovement jump (CMJ), countermovement jump with arm swing (CMJA) and drop jump (DJ). Studies were identified by computerised and manual searches of the literature. It was a survey research design. A total of 26 studies yielding 13 data points for SJ, 19 data points for CMJ, 14 data points for CMJA; and 7 data points for DJ met the initial inclusion criteria. The pooled estimate when expressed in standardised units (i.e. effect sizes), the effect of PT on vertical jump height was 0.44% (95% C10.15 to 0.72), 0.88 (95% c1 0.64 to 1.11), 0.74(95% c1 0.47 to 1.02) and 0.62 (95% c1 0.18 to 1.05), for the SJ, CMJ, CMJA and DJ, respectively. PT provides a statistically significant and practically relevant improvement in vertical jump height with the mean effect ranging from 4.7% (SJ and DJ), over 7.5% (CMJA) to 8.7% (CMJ). In his conclusion about the realised training, the author concluded that plyometric training should be implemented two or three times a week for the development of vertical jump performance in healthy individuals.

Markovic's study is related to this present study in using different plyometric tests on healthy individuals but differs in the methods, population, method of data analysis and intervening variables which is cardiovascular variables and ECG.

Markovic, Jukic, Milanovic and Metikos (2007) compared the effects of sprint and plyometric training with plyometric training on muscle function and dynamic athletic performance. It was a true-experimental research design that lasted for 10 weeks. The researchers used ninety-three male physical education students who were randomly assigned into three groups; sprint group (SG, n= 30), plyometric group (PG, n=30), or control group (CG, n=33). Maximal isometric squat strength, squat and countermovement jump (SJ and CMJ) height and power, drop jump performance from 30cm height, and three athletic performance tests(standing long jump, 20cm sprint, and 20yards shuttle run) were measured before and after the interventions. The data were analysed using t-test paired statistics. Both experimental trained three day per week; SG performed maximal sprints over distances of 10-50m, whereas PG performed bounce-type hurdle jumps and drop jumps. The researchers found that both SG and PG significantly improved drop jump performance, SJ and CMJ height, and standing long jump distance, whereas the respective effect sizes (ES) were moderate to high and ranged between 0.4 and 1.1. The study found out that short-term sprint training produces similar or even greater training effect in muscle function and athletic performance than conventional plyometric training. Markovic, et al.' s study is similar to the present study because both studied focused on effect of plyometric training on male students and the same method of data analysis. The area of difference is that while Markorvic, et al. compared plyometric with sprint on muscle function, the present study is effect on cardiovascular variables and ECG.

Rahman and Naser (2005) compared the effects of three different training protocols-plyometric training, weight training, and their combination on the vertical jump performance, anaerobic power and muscular strength in Iran. Forty-eight male college students participated in the study. It was a six weeks true experimental research design and the subjects were randomly divided into four groups: a plyometric training group (n=13), a weight training group (n=11), a plyometric plus weight training group (n=14), and a control group (n=10). The vertical jump, the 50-yard run and maximal leg strength were measured before and after the training period. Subjects in each group trained two days per week, whereas control group did not participate in any training activity. The data were analysed by One-way Analysis of Variance (ANOVA). The results showed that all the training treatments elicited significant ($p<0.05$) improvement in all the tested variables. However, the combination training group showed signs of improvement in the vertical jump performance, the 50 yard dash, and leg strength that was significantly greater than improvement in the other two training groups (plyometric training and weight training). This study provides support for the use of a combination of traditional weight training and plyometric drills to improve the vertical jumping ability, explosive performance in general and leg strength. Rahman and Naser's study is related to the present study in that both studies were on effect of plyometric training on male students. However, while Rahman and Naser compared the effect of three different protocols and analysed the data using ANOVA, the present study was on effect of lower and upper body plyometric training on cardiovascular variables and ECG using ANCOVA. In addition, Rahman and Naser's study was true experimental carried in Iran while this study was quasi-experimental research design carried in Nigeria.

Abass (2005) studied the relationship among strength, endurance and power performance characteristics of untrained undergraduates following three different modes of plyometric training. It was a survey research design that lasted for twelve weeks. Participants were forty untrained volunteer male undergraduates, randomly assigned to three experimental plyometric training groups of depth jumping, rebound jumping and horizontal jumping over a distance, and a fourth group which served as the control. The three experimental groups were made to go through a 12-week exercise programme based on plyometric training procedures. Interval training method was adopted while the progressive resistance training principle was considered to determine the duration and intensity of training. Data collected were analysed using the mean, standard deviation and range. Relationship between variables was determined using the Pearson Product Moment Correlation Coefficient. Results showed that there were no significant relationships among the groups in strength and endurance performance characteristics. Significant correlation was recorded in power performance between horizontal jumping and rebound jumping group. All other interactions among the groups on leg power were not significant. On relationship among the three variables based on pooled data across the groups, significant correlation was recorded only between muscle strength and power. The researcher found out that correlation between all other variables was not significant. The researcher then concluded that plyometrics training with repeated jumps horizontally and that which involves rebound jumping on the spot, are capable of improving leg muscle power in similar ways. The study also concluded that plyometric training is capable of improving leg muscle strength and power significantly.

Both studies showed that plyometric training had influence on male university students. However, while Abass studied untrained university undergraduates the present study was on healthy trained athletes. In addition, the above study was a correlational study with bigger population; the present study is quasi- experimental study on plyometrics and cardiovascular variables plus ECG.

Similarly, Gehri, Ricard, Kleiner and Kirkendall (1998) compared which plyometric training technique is best for improving vertical jumping ability, positive energy production and elastic energy utilisation using twenty-eight college students. The subjects were then randomly assigned to one of three groups: control group, CMJ training group or DJ training group. The controls continued to perform their regular aerobic exercise. Data were collected before and after 12 weeks of jump training and were analysed by ANOVA. The subjects performed jumps under three testing conditions-squat jump, countermovement jump and depth jump. It was a twelve-week programme that resulted in significant increases in vertical jump height for both training groups. The depth jump group significantly improved their vertical jump height in all three jumps. None of the training methods improved utilisation of elastic energy. In activities involving dynamic stretch-shorten cycles, drop jump training was superior to countermovement jump training due to neuromuscular specificity. This study provides support for the strength and conditioning professional to include plyometric depth jump training as part of the athlete’s overall programme for improving vertical jumping ability and concentric contractile performance.

Adams, O’Shea, O’Shea and Climstein (1992) conducted a study on the effectiveness of three training programmes squat (S), plyometric (P) and squat-plyometric (SP) in increasing hip and thigh power production as measured by vertical jump. The study lasted for six weeks and forty-eight athletes were used as the population of the study. The subjects were randomly grouped equally into four groups; S, P, SP or control (C). The subjects trained two days a week for six-week periodized S, P, or S training programme. Hip and thigh power were tested before and after using the vertical jump test, and the alpha level was set at 0.05. The data were analysed using one-way ANOVA. Statistical analysis of data revealed a significant increase in hip and thigh power production, as measured by vertical jump, within all three treatment groups. The SP group achieved a statistical greater improvement ($p<0.0001$) than the S or P groups alone. The researchers found out that both S and P training were necessary for improving hip and thigh power production as measured by vertical jumping ability. Adams et al.’ s study is related to the present study in that both studies used athletes but differed the effects on cardiovascular variables and ECG, a gap the present study wants to fill.

Effects of Plyometric/Strength Training on Cardiovascular Variables

Arazi, Asadi, Seyed and Seyed (2014) investigated the influence of a session of plyometric exercise (PE) with differing workload on responses of diastolic BP (DBP), HR and systolic BP (SBP) and consequently, of the rate pressure product (RPP) in male athletes. It was a true-experimental research design that lasted for eight weeks. Ten male athletes volunteered to participate in the study. All subjects underwent PE protocols involving 5x10 repetitions (Low workload=LW), 10x10 repetitions (Moderate workload=MW) and 15x10 reps (High workload= HW) depth jump exercise from a 50-cm box at least three times a week for 90 minutes. After each exercise session, SBP, DBP and HR were measured on the left upper arm by the auscultation method using a sphygmomanometer and a stethoscope. An evaluator assessed the SBP via auscultation and DBP at rest and after PE protocols for every 10 minutes. The rate pressure product (RPP) was calculated as SBP x HR (mm Hg x bpm), as it is considered a reliable predictor of myocardial oxygen demand. Data were analyzed using a Two-way repeated measures ANOVA followed by the Bonferroni post hoc test, where indicated, was used to analyse SBP, DBP, HR, and RPP. The level of significance was set at $p<0.05$ for all statistical procedures. All analyses were conducted using SPSS version 16.0 (SPSS Inc, Chicago, IL, USA). No significant difference was observed among post-exercise SBP and DBP when the protocols (LW, MW and HW) were compared. All workloads showed significant increases in the SBP until the 50th minute of post exercise. In DBP, no significant changes were observed for LW, whereas significant increases were seen at the 10th minute of post-exercise for MW and HW. Also, the HW protocol maintained significant increases in the post-exercise DBP until the 20th minute of post-exercise. The above findings showed that all protocols increased SBP, HR and RPP responses at the 10th and 20th minute of post-exercise. With regard to different workloads of plyometric exercise, HW condition indicated greater increases in HR and RPP and strength and conditioning professional athletes must keep in their mind that HW of plyometric exercise induces greater cardiovascular responses.

The above study is related to the present one in that both studies showed plyometric training and cardiovascular variables on male athletes and on the method of analysis but differed in location and ECG variable which the present study measured to determine the effect in Nigeria.

Arazi, Asadi, Rahimzadeh and Moradkhani (2013) compared the effects of high, moderate and low intensity plyometric exercise on the post-exercise systolic and diastolic blood pressure and heart rate responses. It was a quasi experimental research study that lasted for eight weeks. Ten healthy normotensive men volunteered to participate in this study and were evaluated for three non-consecutive days in depth jump exercise from 20cm box (low intensity), 40cm box (moderate intensity) and 60 cm box (high intensity) for five sets of twenty repetitions. After each exercise session, systolic blood (SBP), diastolic blood pressure (DBP and heart rate (HR) were measured every 10 minutes for a period of 90 minutes. The data were gathered and analysed using ANOVA. The result showed that no significant difference was observed among post-exercise SBP, DBP and HR when the protocols were compared. The low intensity and high intensity protocols showed greater reduction in SBP at 40-70th minutes of post exercise whereas the low intensity and moderate intensity indicated greater reduction in10-50th minutes of post exercise. In addition, the change in the DBP for high was not significant and the increases in the HR were similar for all intensity. It was therefore concluded that plyometric exercises can reduce SBP and DBP post-exercise and hence plyometric exercise has significant effects for reducing BP and HR or post-excise hypotension.

Arazi et al.’ s study is similar to the present study because both are similar in design and in using volunteered male athletes but differ in population, location, duration of the study and use of ECG to determine the effects of plyometric training. In addition, Arazi et al.' s study compared the effect of different intensity of plyometric intensities on cardiovascular variables while the present study used only low to moderate intensity.

Ankur and Maulik (2013) in another study sought to find out the comparative effect of exercise intensity on cardiovascular variables during concentric and eccentric resistive knee extension on healthy males. The study was conducted in City Hospital Research and Diagnostic Centre, Physiotherapy Department, Mangalore. It was a true experimental study that lasted for ten weeks. A sample of fifty female healthy subjects between the age group (18-25 years) were randomly selected and divided into two groups, A (Concentric exercise) and B (Eccentric exercise). Each group exercised knee extension at three different intensities 75% of 1 RM, 85% of 1 RM. 5 minutes warm up was given and 5 minutes rest was given after each exercise. SBP, DBP, HR, MAP and RPP were measured before and after each exercise. Statistical analysis done with related t-test and unrelated t-test. Both groups improved but significantly more improvement was seen in concentric group when compared to eccentric group. The result of the study suggested that eccentric exercise produced lower cardiovascular responses than concentric exercise.

The above study is related to the present one in that both studies compared the cardiovascular variables of healthy individuals within the same age bracket but with different sex. On the other hand, both studies are different because Ankur and Maulik concentrated on cardiovascular variables of large population only in Mangalore while the present study compared the effect of plyometric training on cardiovascular variables and ECG of smaller population in Nigeria.

Moro, Ewan and Gerardo (2013) investigated the safety way of training by monitoring the blood pressure and heart rate during one session of resistance training technique of different intensity and compared it to common protocols proposed by ACSM guidelines. The study was conducted in Italy. It was a true experimental study that lasted for two weeks. Twenty healthy volunteers were randomly assigned to one of the two training groups and performed one session of both types of resistance training; high intensity resistance training technique consists of six repetitions, 20 rest, two/three repetitions, 20 rest, two/three repetitions with 230 rest between sets; strength training consisted of three sets of fifteen repetitions with 15 rest between sets. The first day the participants familiarised themselves with the machine and practiced the training technique. The second day (three-four days after familiarisation session) they performed pre-testing. The researchers measured blood pressure (BP) and heart rate (HR) during exercise and later calculated the mean arterial pressure (MAP) and the rate pressure product (RPP); basal lactate was also measured after each session. The analysis of data was done using t-test paired statistics. The subjects showed similar HR response to both training (HIRT=128,20±15,64; TT=116,29± 14,78), also minimal and maximal value were not significantly different (HIRT=89,50± 18,39 and 149,33± 16,26; TT=84,33± 15,23 and 150,00± 16,12). Any difference also in SBP (HIRT=134, 82± 13, 90; TT= 128, 87± 12, 46) or DBP (HIRT=73, 38± 10, 90; TT=73, 94± 9,66) interesting was the analysis of maximal and minimal BP and MAP value: during HIRT subjects reach level of DBP minor than during TT ($p<0.05$) only in TT. Subjects showed the same cardiovascular response to different intensity of resistance training. Furthermore, DBP, that is most important BP parameter, reached lower level during HIRT than TT. The results of this study suggested that HIRT could be a safety way of training, and it could be propose to control obesity.

Moro, et al.'s study and the present study are similar in population using healthy volunteered students and assessment of cardiovascular responses following the plyometric training. The studies differ in the administration of ECG with main focus on male athletes, duration of the programme, location, method of data analysis and instrument for data collection.

Another study was carried out by Arazi, Asadi, Nasehi and Delpas (2012) on the assessment of the acute effects of plyometric exercise on cardiovascular responses, as well as blood lactate concentrations in female volleyball and handball players. It was a quasi experimental research design that lasted for fourteen days. Eight semi professional volleyball players and ten handball players volunteered to participate in the study. Subjects performed five sets of box jumps and depth jumps with ten repetitions, respectively. After each set of exercises, blood pressure and heart rate were assessed. Blood lactate concentration was measured before and after exercise. Muscle soreness was also measured immediately before and immediately after plyometric exercise as well as 24, 48 and 72 hours after plyometric exercise. The data were gathered and analysed using mean, standard deviation and t-test paired statistics. No differences were found in any physiological indices between volleyball and handball players, except heart rate during box jump set two and the rate pressure product (RPP) during box jump set two, five and set one ($p>0.05$). Plyometric exercise increased heart rate, systolic and diastolic blood pressure, and RPP after each set of exercises ($p<0.05$). Plyometric exercise did not induce any significant changes in muscle soreness ($p>0.05$). These findings suggested that plyometric box and depth jumping could be used in an overall programme to properly prepare athletes for competition in events that require both aerobic and anaerobic metabolism components.

Arazi, et al.' s study and the present study are similar in that both study assessed of the effect of plyometric training on cardiovascular responses of volunteered university athletes with the same research design. The studies differ in method of data analysis, the duration of the programme and the population of the study. In addition, Arazi, et al. concentrated their studies on female athletes Islamic Azad University Roudbar, Iran while the present study concentrated on male athletes of Nnamdi Azikiwe University in Anambra State. The present study added administration of the ECG while Arazi et al.'s study did not.

Suleen, Satvinder, Hills and Sebely (2012) investigated the effect of moderate-intensity resistance, aerobic, or combined exercise training on blood pressure and arterial stiffness in overweight and obese individuals compared with no exercise. Ninety-seven participants were randomised to four groups; control, aerobic, resistance, and combination. It was a true experimental research design in which assessments were made at baseline-week eight and week twelve. Data were gathered and analysed using analysis of variance ANOVA. In participant-designed responders, those in the intervention groups who had improved levels of systolic blood pressure (SBP) or augmentation index (AI), observed a significant decrease of (SBP) in aerobic, resistance, and combination groups at week eight and in the combination group at week twelve, compared with baseline. AI was significantly lower at week twelve in the aerobic, resistance, and combination groups compared with baseline, as well as in the combination group compared with the control group. The authors did not observe any significant change in SBP, DBP or AI when assessed the entire cohort, although there were significant improvement in a subgroup of responders. Both studies are similar in considering the cardiovascular variables but differ in population, location and using ECG. In addition, the above study used overweight and obese individuals while the present study used only healthy male athletes.

Lobo (2012) investigated the effects of two months detraining on physical fitness and cardiovascular health variables in Northeast Portugal. Thirty-seven non-institutionalised elders aged 62 to 81 participated in the study. It was a longitudinal study that lasted for one year with a multi-componential physical activity programme. The subjects were reevaluated after a two-month post-intervention for the detraining period. Thirty-seven non-institutionalised subjects (five men; thirty-two women) were randomly assigned from an elders association with fourteen men and seventy-seven women. Habitual physical activity (Baecke questionnaire), physical fitness (Functional Fitness Test), body composition (BMI and waist measure), blood plasma lipid and glucose concentrations were also assessed. All statistical analyses were conducted using SPSS (version 17.01). Pearson correlation was used to determine the relationship between the variables differences within the group in pre and post intervention, detraining values were performed by one-way analysis of variance (ANOVA). Scheffe was also used for Post-hoc comparisons. The result demonstrated that detraining significantly affected lower body components and the agility/dynamic balance, while there were significant changes in the cardiovascular variables. The findings indicated that favorable physical activity adaptations were lost within two months of detraining. Therefore, elders should follow a long-term and systematic exercise routine throughout life, in order to improve and maintain their physical functions and to ameliorate their cardiovascular functions. Lobo's study is different from the present study in the sense that while Lobo concentrated on non-institutionalised elders and physical fitness, the present study is focused on effect of plyometric training on young healthy male university athletes. In addition, Lobo used a longitudinal survey research design with larger population while the present study was quasi-experimental research study with twenty-six subjects in Nigeria.

Chaudhary, Manpreet and Sandhu, 2010) compared the effects of aerobic versus resistance training on cardiovascular fitness in obese sedentary females. It was a quasi experimental research design. Thirty obese women, aged 35-45 years with body mass index (BMI) of above 30 were used for the study. Subjects were grouped into any of the three groups: control (n-10), aerobic training (n-10) and resistance training (n-10). Aerobic training was given for three days a week at 60-70% of maximum HR while resistance training was given for alternate days for six weeks. HR, blood pressure and recovery HR were measured before and after the exercise. Data were analysed using t-test paired statistics. The results of the study indicated statistically significant differences in recovery heart rate and in post-diastolic blood pressure. Significant differences were also observed in very low-density lipoprotein and HDL, post–exercise levels in aerobic training group with $p<0.001$. BMI and body fat percent showed significant improvements in both training groups. The researchers concluded that aerobic training is more beneficial and can be used as a preventive measure in patients who are at risk of developing cardiovascular diseases due to obesity.

The above study is related to the present one in that both studies were quasi experimental research design and compared the cardiovascular variables but differ in ECG, location, method of data analysis, population, duration and type of training. In addition, the present study concentrated on healthy male university athletes while Chaudhary, et al.'s study used the obese sedentary females.

Bhavna and Sarika (2010) conducted a study on the effects of concentric vs eccentric loading on cardiovascular variables and ECG in Amritsar. It was a true experimental research design that lasted for eight weeks. Twenty young healthy students were used and were randomly divided into two groups, experimental and control. Pretest and post training reading were taken for the following parameters- heart rate, blood pressure, mean arterial pressure, rate pressure product and ECG. At the first testing bout, participants performed concentric exercises at 75% of 10 RM. Participants returned ten days after the first session to perform exercises using eccentric contraction type. Related t-test and one way ANOVA were used for statistical analysis between groups. Cardiovascular measures collected from subjects were significantly lower during eccentric than during concentric bouts in all subjects ($p<0.01$) and ECG showed no significant changes after both training protocols ($p>0.05$). So it was concluded that since eccentric exercises produce less cardiopulmonary demands, they are more suitable for persons with low exercise tolerance, who are at the risk of adverse cardiopulmonary events and for improving and maintaining cardiac fitness.

The above study is related to the present one in that both studies showed cardiovascular and ECG effect of healthy individuals using eccentric and concentric exercises. They are also similar in methods, population and method of analysis. On the other hand, both studies are different because Bhavna and Sarika concentrated their studies on Guru Nanak Dev University, Amritsar while the present study concentrated on male athletes of Nnamdi Azikiwe University, Awka.

Williams (2006) investigated the effects of a 10-week aerobic exercise training programme on cardiovascular variables and to predict change of blood pressure in pre-hypertensive African and American women. It was a true experimental research study. A total of twelve sedentary women that met the inclusionary criteria were taken to participate in the study through three pre-training visits. These visits include orientation, pre-VO_2peak test, and pre-CO_2 re-breathing test. Orientations consisted of paperwork explaining confidentially through HIPPA regulation and inform consent. The VO_2peak test was performed on a cycle ergometer using a two minutes protocol while monitoring with a standard 12-lead ECG system. The third visit consisted of a standard procedure of indirect non-invasive CO_2 re-breathing test to determine CO, SV and TPR. The CO_2 re-breathing test was performed on a cycle ergometer while monitoring with the ECG system. Following testing subjects (n=12) trained for 10 weeks three times a week thirty minutes a session at 70% of their VO_2 peak with increases of intensity every two half weeks. Once trained was completed, the subjects repeated the VO_2 peak test and CO_2 re-breathing test to obtain post values. Using the SPSS statistical analysis software and a paired sample t-test, the researcher observed that there were not any significant changes from pre- and post-training for HR, SBP, DBP, and MAP. However, there were significant changes ($p<0.05$) from pre-to post-training in VO_2 peak, SV, CO and TPR. $V0_2$ peak increased from 19.05 $\pm$3.92ml/kg/min to 23.02$\pm$3.92ml/kg/min. SV increased from 34.17$\pm$11.82ml/kg/min to 43.83$\pm$14.03ml/kg/min. CO increase from 3.12$\pm$0.99L/min to3.99L/min. TPR decreased from 35.56$\pm$17.67mmHg* L/min to

27.00±14.9567mmHg*L/min. Six subjects decreased either SBP or DBP to normotensive values. The result of the study has shown that exercise can result in beneficial in pre-hypertensive African American women. However, it could not answer the question asked. However, with control of menstruation a future study may demonstrate a decrease in blood pressure and then a prediction may be observed. Since the expected variables increase accordingly to the recent studies. The elements of the training programme are not needed to be modified.

The above study is related to the present one in that both studies considered the cardiovascular responses to exercise. In addition, this present study differs in the assessment of lower and upper body plyometric training, while Williams used aerobic exercise training programme. In addition Williams used sedentary African American women while this present study focused on apparently healthy male university athletes of Nnamdi Azikiwe University.

Summary of Reviewed Literature

In line with the literature reviewed for this study, plyometric is a form of specialised strength training that uses fast muscular contractions to develop a forceful movement and was developed by Yuri Verkhoshansky. Plyometric training involves preloading of the muscle using an eccentric (lengthening) action, followed immediately by a concentric (shortening) action. This process of contract-lengthen, contract-shorten is known as the stretch-shortening cycle. It has many benefits which include easily calibrated to suit anyone’s needs and no extreme exercise equipment is needed. Types of plyometric exercises for both lower and upper extremities with different intensities were also reviewed. Plyometric exercises, like other forms of fitness training carry risk when used incorrectly and recklessly. The safety of plyometric exercises depend on certain considerations on the age, basic strength, good technique, body weight and rapidity of stretch which may help to avoid injuries when using plyometric in a training workout.

Equally reviewed were cardiovascular variables such as heart rate, blood pressure- systolic blood pressure, diastolic blood pressure, mean arterial pressure, rate pressure product, cardiac output and stroke volume. During incremental exercises to maximum, heart rate, systolic blood pressure, cardiac output and rate pressure product increase in a rectilinear fashion with increasing workload. Diastolic blood pressure remains relatively constant throughout an incremental exercise test while stroke volume increases initially and the plateaus. Independently, the decrease in blood pressure (BP), heart rate (HR), mean arterial pressure (MAP) and pressure product (RPP) reduces the risk of cardiovascular diseases such as arterial hypertension.

Empirical review showed that plyometric training has been a useful training technique for optimising performance in most popular sports by coaches and athletes in the preparation for professional competitions, but its effect on athletes' cardiovascular system especially on blood pressure (BP) and ECG have not been described. From the literature reviewed for this study, only a few studies have attempted to compare the cardiovascular responses to plyometric training. These studies either employed eccentric, concentric or stretching exercises but do not mention plyometric, others used plyometrics but focused on the patients, obese or older individual not young athletes and without including ECG.

The review of related literature showed that there is an existing gap, for most of the studies in this area were done outside the country. Even the one done in Nigeria by Abbas, was done outside Anambra State and it was a survey study. Only Bhavna and Sarika used ECG on healthy individuals using eccentric and concentric exercises in Amritsar, but do not mention plyometric training and the present study concentrated on male university athletes in Awka. It is based on these that this study was designed to investigate the effects of lower and upper body plyometric training on the cardiovascular variables and ECG of male athletes in Nnamdi Azikiwe University, Awka. The findings of this study would help to close this existing gap.

CHAPTER THREE

METHOD

In this chapter, the method that was used in carrying out the study is presented and discussed under the following headings: research design, area of the study, population of the study, instrument for data collection, validation of the instruments, reliability of the instruments, experimental procedure, measurements, training procedure, control of extraneous variables, description of treatment variables, method of data analysis.

Research Design

The study adopted a quasi-experimental research design. It was pretest, posttest and control group but no randomization. It is a design where the observations are made in the study groups before and after interventions and subjects are assigned to groups but without proper randomisation (Akubueze, 2010). This research design was deemed appropriate as this study was basically to find out the cause and effect relationship between the plyometric training, cardiovascular variables and ECG of male university athletes using intact groups (without randomisation).

This design was also considered appropriate because it was not possible to place subjects in groups by random assignment without disrupting the athletes in their team groups and the training venues. Also the subjects in both the treatment and control groups differ by number and they were not equal at baseline. The subjects were purposively assigned into one of the three groups: two experimental groups using LBPT, UBPT and Control based on the type of sports the athlete plays.

In addition studies by Suhrcke and Nieves (2011) used quasi-experimental research design to study the impact of health and health behaviors on educational outcomes in high-income countries: a review of the evidence. Moro, et al. (2013) also used this design to monitor the effect of blood pressure and heart rate to two resistance training techniques of different intensity in Italy. Furthermore, Sankarmani, et al. (2012) equally used quasi-experimental research design in studying the effectiveness of plyometrics and weight training in anaerobic power and muscle strength in female athletes in India, which was considered appropriate to be adopted and used in this study. Symbolically, this design can be represented as shown in table 4.

Table 4: Design of the Experiment

Groups	Pretest Treatment		Posttest
Group A	P1	X1	P2
Group B	P1	X2	P2
Group C	P1	C	P2

Where:

P1 represents pretest with all the groups (LBPT, UBPT and Control)

P2 represents posttest with all the groups (LBPT, UBPT and Control)

X1 represents experimental treatment using LBPT

X2 represents experimental treatment using UBPT

C represents Control or No Treatment

Area of the Study

The study was conducted in Nnamdi Azikiwe University, Awka. Nnamdi Azikiwe University, Awka has four campuses namely Awka, Nnewi, Agulu and Ifite-Ogwari. Only Nnewi Campus was used for the study. Nnewi Campus is located in the outskirt of Otolo village in Nnewi North Local Government Area in Anambra State. It has a common boundary with Ukpor and Uttuh. It has three faculties namely Faculty of Medicine, Faculty of Health Sciences and Technology and Faculty of Basic Medical Sciences with a total of twenty-two departments. It has a population of 3,500 students according to records from bursary unit of the university. Due to the geographical location of Nnewi campus, students living very close to the campus utilise university sports facilities to meet their recreational needs. These sports facilities include; standard football pitch, basketball court, badminton court, volleyball court and table tennis and a few others. The rationale for this choice by the researcher was based on the fact that the medical students belong to different team events and they have their biennial games called Nigerian Medical Students Association Games (NIMSA) to attend and the accessibility of both sports facilities and the laboratory where the athletes can be tested and measured using ECG machine.

Population of the Study

The target population of this study consisted of all the male athletes in Nnamdi Azikiwe University, Nnewi Campus. However, only the volunteered male athletes were used for the study. Seventy –two university male athletes aged 18 to 24years constituted the population of the study. Thirty male athletes volunteered to participate in the study, but only twenty-three completed the study. The volunteered athletes were apparently healthy, physically active, and free of any lower and upper extremity bone injuries for past one year and they had no medical or orthopedic injuries that may affect their participation in the study. Ten subjects each were purposively assigned to one of the three groups: lower body plyometric training (LBPT), upper body plyometric training (UBPT) and control (C) based on the type of sports the athlete plays.

Instrument for Data Collection

Two instruments were used for the collection of data for this study. They were Automated Blood Pressure Monitor and a Standard 12-lead Electrocardiogram (ECG) system. These instruments were modern standardised equipment graduated in mmHg.

A modern automated blood pressure with monitor was used to determine the systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) of the male university athletes. It is measured in mmHg. According to The American Heart Association (2014), an automated calibrated blood pressure monitor is a device used to measure blood pressure and heart rate. A Standard 12-lead ECG system was also used to the electrical activity of the heart (P wave, QRS complex and T wave) of male university athletes.

Validation of the Instruments

Four experts validated and confirmed the adoption of the instrument for data collection. Two experts from Physiology Department and two Exercise Physiologists from Nnamdi Azikiwe University, Awka validated and confirmed the adoption of the instrument for data collection. Standardised modern equipment was used for the study. An Automated Digital Blood Pressure Monitor manufactured by Fudakang Industrial LLC Plainsboro USA with cuff size cuff selection, Model: BP-FC11B and a Standard 12- lead ECG system graduated in mmHg were used as the instruments for data collection.

Reliability of the Instruments

To determine the reliability and internal consistency of the blood pressure monitor, a pilot test was carried by the researcher. The instruments were administered to five students at the College of Health Sciences, Nnewi Campus. The students of the college were assumed to be equivalent to the groups for the study. The test item produced the same results. Therefore, the instruments were deemed to be reliable.

Experimental Procedure

Participants had previous strength training experience and were working out on a regular basis. However, these athletes neither had previous plyometric training experience nor were they undergoing assessment of any cardiovascular response to any exercise.

A week before conducting the study, all participants were gathered at the gymnasium room and received a complete explanation of the purpose of the study and the need to complete the training programme. During this session, each participant was instructed in the proper form and technique of lower and upper body plyometric exercises through explanation of proper technique, demonstration and risk involved (familiarisation session). Pretest and posttest were conducted before and after 10 weeks plyometric training programme. The main variables measured in this study were heart rate, blood pressure, and ECG. Additional variables include age; height and weight (BMI) of the athletes were also measured.

Measurements

Body Mass Index (BMI)

Body mass index (BMI) measure was used as an estimate of body composition. Body height was measured to an accuracy of 1cm, with the subject in an upright position with a Standard Stadiometre. Body weight was measured to the nearest 0.1kg, with subjects lightly dressed and in stocking feet. BMI was calculated using the standard formula: $\{\text{mass (kg)/height (m)}\}^2$.

Blood Pressure

Resting blood pressure (BP) was measured with the automated digital blood pressure monitor (BP-FC11B), using the right arms. Measurements of the systolic blood pressure (SBP), diastolic blood pressure (DBP) and heart rate (HR) were taken within a 10 minutes break. It was measured in a quiet, temperature-controlled room, on the right upper arm by using an automated digital blood pressure monitor taken with the subjects seated in an upright position with the arm comfortably placed at heart level. The rationale for measuring the right arm by the researcher was that most individuals have greater BP measurement taken from the right than the left arm. The average of the three measurements for SBP, DBP and HR were entered as data. The measurements were performed between 9am and 11am, by the researcher to avoid much stress. Subjects were deemed to be hypertensive where their SBP was above ≥ 140mmHg, their DBP was above ≥ 90 mmHg or they were on current anti-hypertensive drug treatment were not allowed to continue with the treatment tests.

More so, mean arterial (MAP) defined as the average arterial pressure in an individual during a single cardiac cycle. However, since the systolic and diastolic blood pressure has been measured, the calculation of MAP is equal to DBP+1/3(SBP-DBP). In addition, the rate pressure product (RPP), which is a physiological index to determine the cardiovascular risk of an individual, as the product of HR and SBP was also calculated which is RPP= HR × SBP.

ECG

The ECG administration was done by an expert from the department of physiology with a 12-lead ECG at the lab before and after the plyometric training programme to measure the electrical activity of the heart (P wave, QRS complex and T wave) of the athletes, after which it was analysed by an expert in the field of cardiology.

Training Procedure

The LBPT and UBPT groups were required to perform three times per week on alternate days (Tuesday, Thursday and Saturday) for 10 weeks. Thus, the programme entailed thirty training workouts for each subjects in both experimental groups. Training session in both experimental groups lasted 50 minutes and began with a 10-minute warm-up: 5 minutes of jogging and 5 minutes stretching exercises, 35 minutes LBPT and UBPT, and 5 minutes cooling down. Both experiments were performed on outdoor with different venues. The training programme employed by each experimental group is outlined in Table 5. It should be stressed that many previous studies used only lower or upper body plyometric training. However, to be able to evaluate the effects of plyometrics on cardiovascular variables, the researcher decided to include ECG in the study. Specifically, the control group was advised to avoid plyometric exercises and continue with their normal training routine. The subjects were also advised to avoid alcohol, caffeine and smoking throughout the period under study.

Table 5: Training programme for the Lower and Upper Body Plyometric Training (LBPT and UBPT)

LBPT Exercise X sets X reps	UBPT Exercise X sets X reps
Wk 1 ankle hops 3 X 3 X 8	push-ups 3 X 3 X 8
Wk 2 ankle hops 3 X 5 X 10	push-ups 3 X 5 X 10
Wk 3 ankle hops 3 X 7 X 10	push-ups 3 X 7 X 10
Wk 4 ankle hops 3 X 8 X 10	push-ups 3 X 8 X 10
Wk 5 squat jumps 3 X 7 X 10	chest throws (medicine ball) 3 X 7 X 10
Wk 6 squat jumps 3 X 8 X 10	chest throws (medicine ball) 3 X 8 X 10
Wk7 squat jumps 3 X 10 X 10	chest throws (medicine ball) 3 X 10 X 10
Wk 8 tuck jumps 3 X 8 X 10	side throws (medicine ball) 3 X 8 X 10
Wk 9 tuck jumps 3 X 10 X 10	side throws (medicine ball) 3 X 10 X 10
Wk 10 tuck jumps 3 X 12 X 10	side throws (medicine ball) 3 X 12 X 10

During the first week, the training intensity was 50-60% of 1RM with one minute rest between sets in order to familiarise themselves with the training. For the remaining nine weeks, the intensity and duration of exercise were gradually increased both in sets and repetitions to accommodate the scientific principle of progressive over-load. From fourth week, the load was raised to 60-70% of 1RM with two-three minutes rest between sets and maintained until the final week of the programme. However, the duration of each training session, as well as the duration of rest between sets, was the same for both groups. Treatment sessions were initiated between 4-6pm. Only low to moderate intensity training was used for the study. The training programme was also based on the interval training principle, which comprised series of plyometrics exercise work intervals, interspersed with relief intervals. The progressive resistance training principle was also used in determining the dosage at every period of training.

Control of Extraneous Variables

The following extraneous variables which were likely to interfere with the dependent variables were taken into considerations thus:

1. **Age and Weight**: All athletes were not equal in age and weight. In order to control this variable in the study, only the male athletes aged 18 to 24years and the body mass index (BMI) within the range of underweight to normal weight (less than 18.5 to 24.9) respectively were used for the study.
2. **Experimental Bias**: The athletes were not camped and they may tend to behave mechanically and fake most of their actions. In order to avoid bias in the study, the following conditions were given to the participants in order to minimise experimental bias that would likely interfere with the dependent variables:
   a. To abstain from alcohol, caffeinated drinks, smoking or stimulants for 24 hrs before the training and throughout the intervention.
   b. To take a light meal two hours before the experiments and to avoid much stress before the interventions.
   c. Not to perform any plyometric exercise within two days before the interventions.
   d. Subjects were also instructed on the importance of the study in order to avoid stopping half way without completion of the regular training programme.
   e. Measurements of BP were made simultaneously in the right arm, and to avoid disparities the average of the three measurements were entered as data.
3. **Measurement Variable**: Subjects who were deemed to be hypertensive where their SBP was ≥ 140 mmHg, their DBP was $\geq 90mmHg$ or they were on current anti-hypertensive drugs treatment were not allowed to continue with the treatment tests. For uniformity of the

measurement, BP was measured by the researcher alone throughout the programme while the expert handles the administration of the ECG.

4. **Athlete's Interaction:** The researcher was aware of the possible interaction between the athletes in the experimental and control groups. As a result of this, the training venues differed. They were not in the same training venue. The athletes in the control group were asked to continue their usual training routine but without including plyometric exercises.

Description of Treatment Variables

Six treatment variables were used for the study. They were three lower body plyometric training (ankle hops, squat jumps and tuck jumps) and three upper body plyometric training (plyometric push-ups, squat throws and side throws) (Comyns, 2012).

Ankle Hops

Step 1: Stand with your feet shoulder width apart and rise up on your toes.

Step 2: Jump 3-6 inches off the ground and as soon as you land jump back up again.

Step 3: Keep your legs straight as you jump and do not let your heels touch the ground.

Step 4: Repeat for the desired amount of repetitions. (See Appendix B, pp.154)

Squat Jumps

1. Stand with feet shoulder width apart, trunk flexed forward slightly with back straight in a neutral position.
2. Arm should be in the "ready" position with elbow flexed at approximately at 90◦.
3. Lower body where thighs are parallel to the ground and immediately explode upwards vertically and drive arms up. Do not hold a squat position before jumping up.
4. Keep the time between dipping down and jumping up to a minimum.
5. Land on both feet, rest for 1-2 seconds and repeat.

6. Prior to take off, extend the ankles to their maximum range (full plantar flexion) to ensure proper mechanics. (See Appendix C, pp.155)

Tuck Jumps

1. Stand with feet shoulder- width apart, knee slightly bent, with arms at the sides.
2. Jump up bringing knees up to chest.
3. Land on balls of the feet and repeat immediately.
4. Remember to reduce ground contact time by landing soft on feet and springing into the air.(Appendix D, pp.156)

Plyometric Push-ups

1. Assume a normal push-up position.
2. Lower yourself to the ground and then explosively push-up so that your hands leave the ground.
3. Catch your fall with your hands and immediately lower yourself into a push-up again.
4. Repeat for the desired amount of repetitions. (Appendix E, pp.157)

Medicine Ball - Squat Throws

1. Stand with feet slightly wider than hip-width apart, knees should be slightly bent.
2. Hold medicine ball at chest level and squat down to a parallel position.
3. Quickly explode up and jump as high as you can. As you start your jump, you should start to shoulder press the ball up and reach fill extensions with the arms when you are at the peak of your jump, push ball as high as possible into the air. Try to minimize the time spent in the squatted position. It should be as a quick squat and jump.
4. Catch ball on the bounce from the partner or wall and repeat according to prescribed repetitions.

Medicine Ball - Side Throws

1. Stand with feet hip-width apart, place left foot approximately one foot in front of right foot.
2. Hold medicine ball with both hands and arms only slightly bent.
3. Swing ball over to the right hip and forcefully under hand toss ball forward to a partner or wall. Keep the stomach drawn in to maximise proper usage of muscle.
4. Catch ball at the bounce from your partner or wall and repeat. (Appendix J, pp.162)

Method of Data Analysis

The general data were collated and analysed using Statistical Package for Social Science (SPSS version 22.0). The research questions were answered with mean and standard deviation, while statistical analysis were performed by analysis of covariance (ANCOVA).The level of significance was set at $P \leq 0.05$. However, ANCOVA was used in the study since the volunteered athletes were used intact without proper randomisation which indicated that the subjects were not equal at the baseline and the population was small. ANCOVA removes the initial differences between groups so that the selected or pretested groups can be correctly considered as equivalent for generalisation. This implies that ANCOVA is a statistical tool that sits between analysis of variance and regression analysis (Siegle, 2013). The ANCOVA was also considered adequate for testing these hypotheses since it serves as a procedure for controlling the initial differences across the groups like age, height and weight by partitioning out the variation due to extraneous variables thereby increasing the precision of the experiment.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF DATA

This chapter presents the analyses of data generated from this study and the summary of major findings. Summary of the major findings are presented according to the research questions and hypotheses that guided the study.

Research Questions

Research Question 1

What is the mean heart rate (HR) of university athletes who were trained using lower body plyometric training and those in the control group?

Data in table 6 are used to answer research question one

Table 6: Mean and Standard Deviation scores on HR of athletes who were trained using LBPT

HR		Pretest		Posttest	
	N	Mean ($\bar{X}$)	SD	Mean ($\bar{X}$)	SD
LBPT Group	8	63.38	10.81	56.38	7.27
Control	8	67.00	7.80	61.50	7.98

Table 6 shows the mean and standard deviation HR scores of athletes who were trained using LBPT. The result revealed that athletes who were trained using LBPT had reduced posttest mean and standard deviation scores of HR (56.38 $\pm$ 7.27) better than their counterparts in the control group (61.50$\pm$ 7.98).

Research Question 2

What is the mean systolic blood pressure (SBP) of male university athletes who were trained using lower body plyometric training and those in the control group?

Research Question 3

What is the mean diastolic blood pressure (DBP) of university athletes who were trained using lower body plyometric training and those in the control group?

Data in table 7 are used to answer these research questions two and three.

Table 7: Mean and Standard Deviation scores on SBP and DBP of athletes who were trained using LBPT.

Cardiovascular Variables	N	Pretest Mean ($\bar{X}$)	Pretest SD	Posttest Mean ($\bar{X}$)	Posttest SD
LBPT					
SBP	8	110.38	10.14	104.13	8.59
DBP	8	76.38	7.98	66.25	6.45
Control group					
SBP	8	114.50	15.48	107.13	15.08
DBP	8	75.13	10.89	70.25	12.28

Table 7 shows that the athletes who were trained using LBPT had reduced posttest mean scores of SBP (104.13±8.59) better than those in the control group (107.13± 15.08). The data also revealed that athletes who were trained using (LBPT) had reduced posttest mean and standard deviation scores of DBP (66.25± 6.45) better than their counterparts in the control group (70.25± 12.28).

Research Question 4

What is the mean MAP of university athletes who were trained using lower body plyometric training and those in the control group?

Research Question 5

What is the mean rate pressure product (RPP) of university athletes who were trained using lower body plyometric training and those in the control group?

Data in table 8 are used to answer these research questions four and five.

Table 8: Mean and Standard Deviation scores on MAP and RPP of athletes who were trained using LBPT

Variables	Pretest			Posttest	
	N	Mean ($\bar{X}$)	SD	Mean ($\bar{X}$)	SD
Experimental Group					
MAP	8	87.71	8.25	78.88	5.85
RPP	8	6987.25	1344.80	5842.00	651.99
Control Group					
MAP	8	88.53	8.62	82.53	9.53
RPP	8	7602.13	755.25	6648.63	1605.97

The Table 8 shows that the athletes who were trained using LBPT had the reduced posttest mean and standard deviation of MAP (78.88±5.85) better than their counterparts in the control group (82.53±9.53). It also shows that athletes who were trained using LBPT had reduced posttest mean and standard deviation scores of RPP (5842.00±651.99) better than those in the control group (6648.63±1605.97).

Research Question 6

What is the mean P wave on ECG readings of university athletes who were trained using lower body plyometric training and those in the control group?

Research Question 7

What is the mean QRS complex on the ECG readings of university athletes who were trained using lower body plyometric training and those in the control group?

Research Question 8

What is the mean T wave on the ECG readings of university athletes who were trained using lower body plyometric training and those in the control group?

Data in figure 2 are used to answer research questions six, seven and eight.

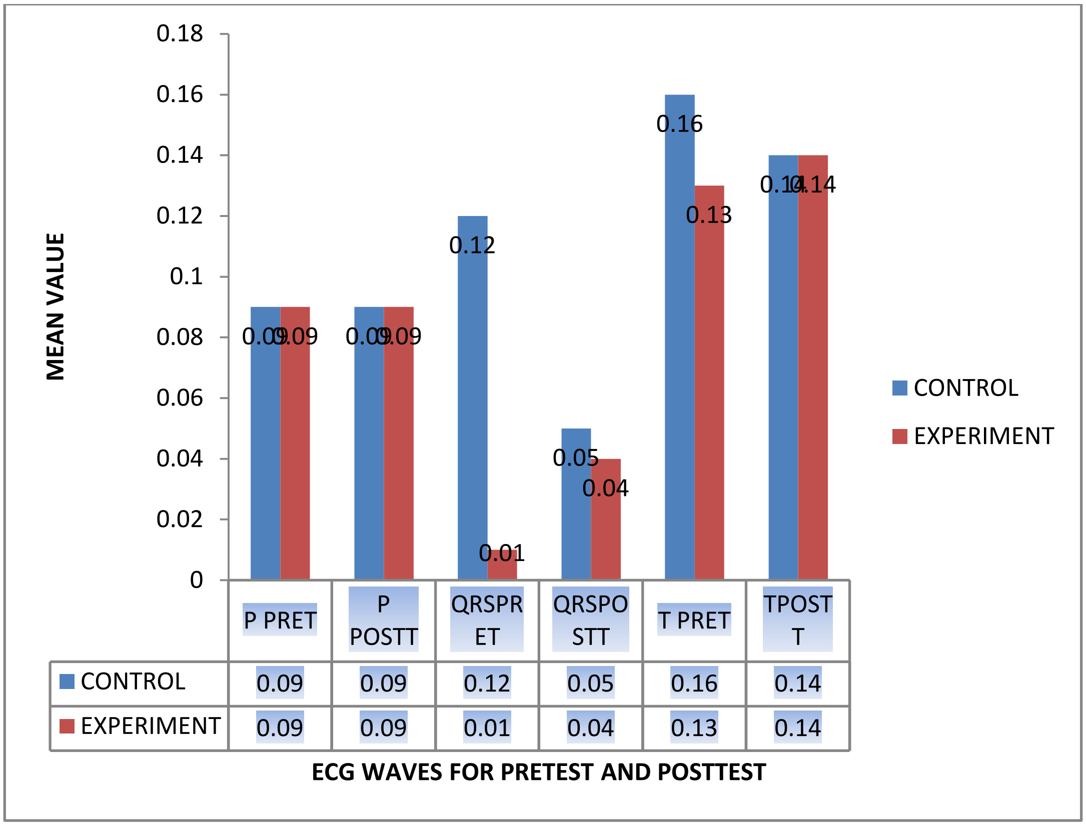

Figure 2: Pretest and Posttest Mean scores on ECG variables of athletes who were trained using LBPT

Figure 2 shows that the athletes who were trained using LBPT had the same posttest mean scores on P wave (.09) with their counterparts in the control group (.09). It also shows that the experimental group (LBPT) had reduced posttest mean scores of QRS complex (.04) better than the control group (.05). Fig. 2 also shows that athletes who were trained using LBPT had slightly posttest mean and standard deviation scores of T wave (.14) with the subjects in the control group (.14).

Research Question 9

What is the mean heart rate (HR) of university athletes who were trained using upper body plyometric training and those in the control group?

Data in table 9 are used to answer research question nine.

Table 9: Mean and Standard Deviation of HR of athletes who were trained using UBPT

Variables		Pretest		Posttest	
	N	Mean (X)	SD	Mean (X)	SD
HR	8	59.13	16.85	56.13	7.34
Control	8	67.00	7.80	61.50	7.98

Table 9 shows the mean and standard deviation scores of HR of athletes who were trained using UBPT. Table 9 revealed that athletes who were trained using UBPT had reduced posttest mean scores of HR (56.13±7.34) better than those in the control group (61.50±7.98).

Research Question 10

What is the mean systolic blood pressure (SBP) of university athletes who were trained using upper body plyometric training and those in the control group?

Research Question 11

What is the mean diastolic blood pressure (DBP) of university athletes who were trained using upper body plyometric training and those in the control group?

Data in table 10 are used to answer these research questions ten and eleven.

Table 10: Mean and Standard Deviation scores on SBP and DBP of athletes trained who were using UBPT.

Variables		Pretest		Posttest	
	N	Mean (X)	SD	Mean (X)	SD
Experimental Group					
SBP	8	110.50	7.48	102.25	4.30
DBP	8	70.50	5.61	72.38	3.81
Control Group					
SBP	8	114.50	15.48	107.13	15.08
DBP	8	75.13	10.89	70.25	12.28

Table 10 shows that athletes who were trained using UBPT had reduced posttest mean scores of SBP (102.25±4.30) better than their counterparts in the control group (107.13± 15.08).The table also revealed that athletes who were trained using UBPT had the highest posttest mean scores of DBP (72.38± 3.81) not better than the control group (70.2500 ± 12.28).

Research Question 12

What is the mean (MAP) of university athletes who were trained using upper body plyometric training and those in the control group?

Data in table 11and figure 3 are used to answer research question twelve

Table 11: Mean and Standard Deviation scores on MAP of athletes trained who were using UBPT.

Variables	N	Pretest Mean (X̄)	SD	Posttest Mean (X̄)	SD
Experimental Group					
MAP	8	83.84	5.00	82.24	3.34
Control Group					
MAP	8	88.25	8.62	82.53	9.53

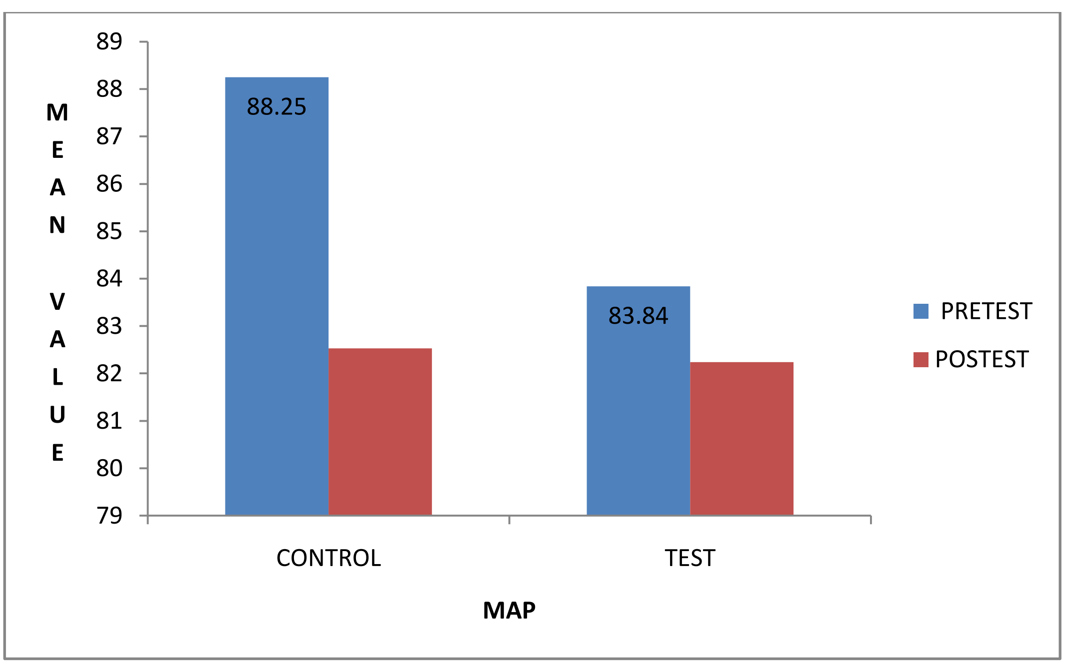

Fig 3: Chart Comparing Pretest and Posttest Mean scores on MAP of athletes trained who were using UBPT

Table 11 and Figure 3 show that athletes who were trained using UBPT had slightly reduced posttest mean scores of MAP (82.24±3.34) better than their counterparts in the control group (82.52± 9.53).

Research Question 13

What is the mean rate pressure product (RPP) of university athletes who were trained using upper body plyometric training and those in the control group?

Data in figure 4 are used to answer research question thirteen

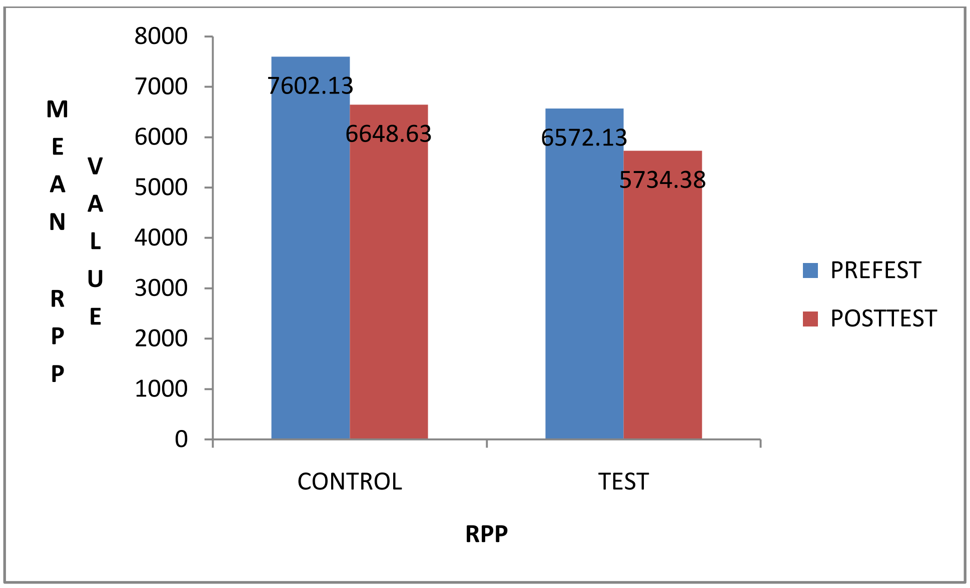

Fig 4: Chart Comparing Pretest and Posttest Mean RPP of athletes trained who were using UBPT

Figure 4 also revealed that athletes who were trained using UBPT had reduced posttest mean scores of RPP (5734.38) better than the control group (6648.63).

Research Question 14

What is the mean P wave on ECG readings of university athletes who were trained using upper body plyometric training and those in the control group?

Research Question 15

What is the mean QRS complex on ECG readings of university athletes who were trained using upper body plyometric training and those in the control group?

Research Question 16

What is the mean T wave on ECG readings of university athletes who were trained using upper body plyometric training and those in the control group?

Data in figure 5 are used to answer these research questions fourteen, fifteen and sixteen

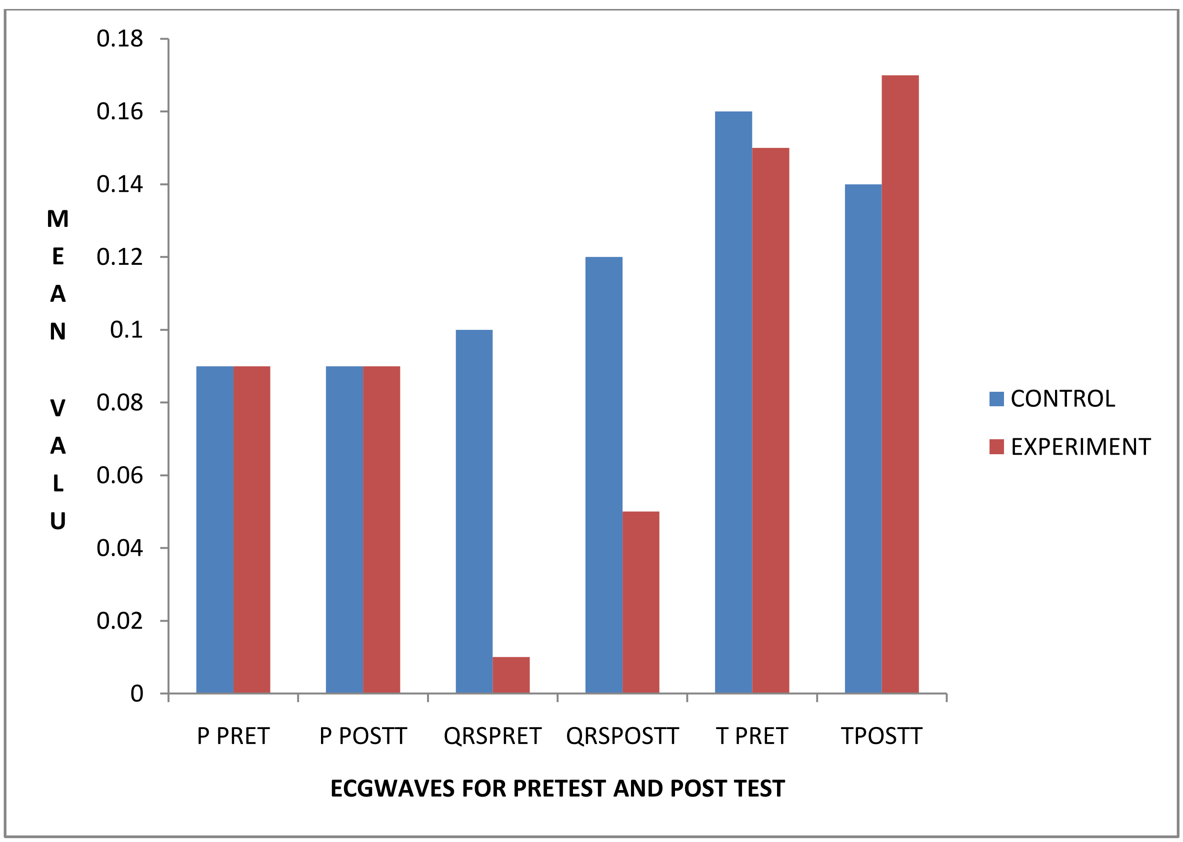

Fig.5: Chart comparing Pretest Posttest Mean scores on ECG variables of athletes who were trained using UBPT

Figure 5 shows that athletes who were trained using UBPT had a better posttest mean scores of P wave (.09) better than their counterparts in the control group (.09). The figure also shows that athletes who were trained using UBPT had slightly posttest mean scores of QRS complex (.05) with those in the control group (.05). Figure 5 also revealed that athletes who were trained using upper body plyometric training had the highest posttest mean scores of T wave (.17) compared to the subjects in the control group that recorded (.14).

Hypotheses

Hypothesis 1

Ho1: There is no significant difference in the heart rate (HR) of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 12: Age, BMI adjusted comparison in HR of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES HR	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	61.50±7.98	56.37±7.26	2.13	0.169
UBPT	61.50±7.98	56.12±33	1.96	0.186

Table 12 shows mean heart rate of athletes who were trained using LBPT and UBPT and their untrained control groups at posttest condition. The result revealed that F-calculated value of (2.13 and 1.96) were greater than the P-value of (0.169 and 0.186) at 0.05 level of significance respectively. Analysis of covariance (ANCOVA) indicated that using LBPT and UBPT have no significant effect on the heart rate of university athletes and those in the control groups. Thus, the null hypothesis (Ho1) was therefore accepted.

Hypothesis 2

Ho2: There is no significant difference in the systolic blood pressure (SBP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 13: Age, BMI adjusted comparison in SBP of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES SBP	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	107.12±15.48	104±8.59	0.20	0.659
UBPT	107.12±15.48	102.25±4.30	0.66	0.432

Table 13 shows the mean SBP of athletes who were trained using LBPT and UBPT and their untrained control groups at posttest condition. The result revealed that F-calculated value of (0.20 and 0.66) were less than the P-value of (0.659 and 0.432) at 0.05 level of significance respectively. Analysis of covariance (ANCOVA) indicated that using LBPT and UBPT have no significant effect on the systolic blood pressure of university athletes and those in the control group. Thus, the null hypothesis (Ho2) was therefore accepted.

Hypothesis 3

Ho3: There is no significant difference in the diastolic blood pressure (DBP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 14: Age, BMI adjusted comparison in DBP of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES DBP	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	70.25±12.27	66.25±6.45	0.59	0.455
UBPT	70.25±12.27	72.37±3.81	0.24	0.628

Table 14 shows mean diastolic blood pressure (DBP) of athletes who were trained using LBPT and UBPT and their untrained control groups at posttest condition. The result revealed that F-calculated value of (0.59 and 0.24) were greater than the P-value of (0.455 and 0.628) at 0.05 level of significance respectively. Analysis of covariance (ANCOVA) indicated that using LBPT and UBPT have no significant effect on the diastolic blood pressure of university athletes and those in the control group. Thus, the null hypothesis (Ho3) was therefore accepted.

Hypothesis 4

Ho4: There is no significant difference in the mean arterial pressure (MAP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 15: Age, BMI adjusted comparison in MAP of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES MAP	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	82.52±9.53	78.87±5.84	0.74	0.406
UBPT	82.52±9.53	82.23±3.34	0.002	0.969

Table 15 shows mean MAP of athletes who were trained using LBPT and UBPT and their untrained control groups at posttest condition. The result revealed that F-calculated value of (0.74 and 0.002) were greater than the P-value of (0.406 and 0.969) at 0.05 level of significance respectively. Analysis of covariance (ANCOVA) indicated that using LBPT and UBPT have no significant effect on the mean arterial pressure of university athletes and those in the control group. Thus, the null hypothesis (Ho4) which predicted no significant difference was therefore accepted.

Hypothesis 5

Ho5: There is no significant difference in the rate pressure product (RPP) of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 16: Age, BMI adjusted comparison in RPP of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES RPP	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	6.6±1.60	5.84±0.65	1.64	0.225
UBPT	6.6±1.60	5.73±0.75	1.97	0.186

Table 16 shows mean rate pressure product (RPP) of athletes who were trained using LBPT and UBPT and their untrained control groups at posttest condition. The result revealed that F-calculated value of (1.64 and 1.97) were greater than the P-value of (0.314 and 0.254) respectively at 0.05 level of significance. Analysis of covariance (ANCOVA) indicated that using LBPT and UBPT have no significant effect on the rate pressure product of university athletes and those in the control group. Thus, the null hypothesis (Ho5) which predicted no significant difference was therefore accepted.

Hypothesis 6

Ho6: There is no significant difference in the P wave on ECG readings of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 17: Age, BMI adjusted comparison in P-Wave ECG reading of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES P-WAVE	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	0.10 ± 0.01	0.09 ± 0.01	1.61	0.252
UBPT	0.10 ± 0.00	0.09 ± 0.01	0.01	0.928

Table17 shows mean P-wave ECG readings of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition. The result revealed that the F-calculated value of (1.61 and 0.01) were greater than the P-value of (0.252 and 0.928) respectively at 0.05 level of significant. Analysis of covariance (ANCOVA) indicated lack of significant differences in P-wave ECG reading of athletes who were trained using the LBPT and UBPT and those in the control group. Thus, the null hypothesis (Ho6) which predicted no significant was therefore accepted.

Hypothesis 7

Ho7: There is no significant difference in the QRS complex on ECG readings of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 18: Age, BMI adjusted comparison in QRS Complex ECG readings of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES QRS COMPLEX	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	0.05 ± 0.01	0.04 ± 0.00	2.25	0.161
UBPT	0.05 ± 0.01	0.05 ± 0.01	0.004	0.949

Table18 shows mean QRS complex ECG readings of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition. The result revealed that the F-calculated value of (2.25 and 0.004) were greater than the P-value of (0.161 and 0.949) at 0.05 level of significant respectively. Analysis of covariance (ANCOVA) indicated lack of significant differences between the LBPT and UBPT and those in the control group. Thus, the null hypothesis (Ho7) was therefore accepted.

Hypothesis 8

Ho8: There is no significant difference in the T wave on ECG readings of university athletes who were trained using lower and upper body plyometric training and those in the control group.

Table 19: Age, BMI adjusted comparison in T-wave ECG readings of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition (ANCOVA)

VARIABLES T-WAVE	CONTROL	MEAN	F-STAT	P-VALUE
LBPT	0.15 ± 0.03	0.13± 0.01	1.98	0.208
UBPT	0.15 ± 0.03	0.15 ± 0.04	0.47	0.515

Table19 shows mean T-wave ECG readings of athletes who were trained using LBPT and UBPT and their untrained controls at posttest condition. The result revealed that the F-calculated value of (1.98 and 0.47) were greater than the P-value of (0.208 and 0.515) at 0.05 level of significant respectively. Analysis of covariance (ANCOVA) indicated lack of significant differences between the LBPT and UBPT and those in the control group. Thus, the null hypothesis (Ho8) which predicted no significant was therefore accepted.

Summary of Major Findings

1. Athletes who were trained using LBPT had reduced posttest mean scores of HR better than their counterparts in the control group (Table 6).
2. Athletes who were trained using LBPT had reduced posttest mean scores of SBP better than those in the control group (Table 7).
3. Athletes who were trained using LBPT had reduced posttest mean scores of DBP better than their counterparts in the control group (Table 7).
4. Athletes who were trained using LBPT had reduced posttest mean scores of MAP better than their counterparts in the control group (Table 8).

5. Athletes who were trained using LBPT had reduced posttest mean scores of RPP better than those in the control group (Table 8).
6. Athletes who were trained using LBPT had the same posttest mean scores of P wave with their counterparts in the control group (Fig. 2).
7. Athletes who were trained using LBPT had reduced posttest mean scores of QRS complex better than the control group (Fig. 2).
8. Athletes who were trained using LBPT had slightly the same posttest mean scores of T wave with those in the control group (Fig. 2).
9. Athletes who were trained using UBPT had reduced posttest mean scores of HR better than those in the control group (Table 9).
10. Athletes who were trained using UBPT had reduced posttest mean scores of SBP better than those in the control group (Table 10).
11. Athletes who were trained using UBPT had highest posttest mean scores of DBP not better than those in the control group (Table10).
12. Athletes who were trained using UBPT had posttest mean scores of MAP slightly reduced than their counterparts in the control group (Table 11).
13. Athletes who were trained using UBPT had reduced posttest mean scores of RPP better than those in the control group (Fig. 4).
14. Athletes who were trained using UBPT had the same posttest mean scores of P wave on ECG with their counterparts in the control group (Fig. 5).
15. Athletes who were trained using UBPT had slightly the same posttest mean scores of QRS complex with those in the control group (Fig. 5).
16. Athletes who were trained using UBPT had the highest posttest mean scores of T wave compared to their counterparts in the control group (Fig. 5).

17. There was no significant difference in the mean scores of HR of athletes who were trained using LBPT and UBPT and those in the control group (Table 12).
18. There was no significant difference in the posttest mean scores of SBP of athletes who were trained using LBPT and UBPT and those in the control group (Table 13).
19. There was no significant difference in the mean scores of DBP of athletes who were trained using LBPT and UBPT and those in the control group (Table 14).
20. There was no significant difference in the mean scores of MAP of athletes who were trained using LBPT and UBPT and those in the control group (Table 15).
21. There was no significant difference in the mean scores of RPP of athletes who were trained using LBPT and UBPT and those in the control group (Table 16).
22. There were no significant differences in the mean scores of P wave on ECG of athletes who were trained using LBPT and UBPT and those in the control group (Table 17).
23. There were no significant differences in the mean scores of QRS complex on ECG of athletes who were trained using LBPT and UBPT and those in the control group (Table 18).
24. There were no significant differences in the mean scores of T wave on ECG of athletes who were trained using LBPT and UBPT and those in the control group (Table 19).

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

This chapter discussed the results of the study, its conclusions, implications of the study, recommendations, limitations of the study and suggestions for further research.

Discussions

The discussion of findings is done under the following headings:

a) Effect of using lower and upper body plyometric training on HR.

b) Effect of using lower and upper body plyometric training on SBP.

c) Effect of using lower and upper body plyometric training on DBP.

d) Effect of using lower and upper body plyometric training on MAP.

e) Effect of using lower and upper body plyometric training on RPP.

f) Effect of using lower and upper body plyometric training on ECG reading.

Effect of using lower and upper body plyometric training on HR.

Results in Table 6 showed that athletes who were trained using LBPT had reduced posttest mean scores of HR with 56.38 bpm better than their counterparts in the control group with 61.50 bpm. It shows that the smaller the SD, the more intact the class in performance and the bigger the SD, the less intact the class in performance. The result in Table 9 also revealed that athletes who were trained using UBPT had reduced posttest mean scores of with 56.13 bpm better than those in the control group with 59.13 bpm. This finding was not supervised because the cardiovascular responses depend on the way in which the load and repetitions are combined. The present study utilised the low to moderate intensity workload. This finding is in agreement with that of Arazi, et al. (2014) as well as Arazi, et al. (2013). The authors found that different plyometric workload increased HR at 10^{th} and 20^{th} minute of post exercise. The moderate workload (MW) and high workload (HW) protocols showed greater increase in HR compared with low workload (LW). This might be as a result of using moderate workload (MW) for coaches must keep in their minds that conditioning professional athletes using HW of plyometric exercise could induces greater cardiovascular response which could be very dangerous to the functioning of the heart and may lead to heart attack or sudden cardiac death.

Moreover, the finding of this study revealed that there was no significant difference in the mean scores of HR of athletes who were trained using lower and upper body plyometric training (Table 12). This finding was not surprising because plyometric training involves lengthening (eccentric) muscular contraction quickly followed by shortening (concentric) muscular contraction. This finding is in line with views of Bhavna and Sarika (2010) to the effect that eccentric and concentric group improved but significantly more improvement was seen in concentric group when compared to eccentric group. The result of the study showed that eccentric exercise produced lower cardiovascular response than concentric exercise. A possible explanation of this could be that the lower and upper body plyometric training involves first the movement of eccentric immediately followed by a concentric muscle contraction. The findings could be attributed to the proper application of plyometric techniques which produced better result. The findings are also in agreement with that of Ankur and Maulik (2013) which revealed that eccentric exercise produced lower cardiovascular response than concentric exercise.

Effect of using lower and upper body plyometric training on SBP

The result from Table 7 shows that athletes who were trained using LBPT had reduced posttest mean scores of SBP better than their counterparts in the control group. Table 10 also showed that athletes who were trained using UBPT had reduced posttest mean scores of SBP better than those in the control group.

Testing of hypothesis two revealed that there was no significant difference in the mean scores of SBP of university athletes who were trained using LBPT and UBPT and those in the control (See Table 13). However, the findings of the study supported what was initially stated by Arazi, et al. (2013) that the low intensity and high intensity protocols showed greater reduction in SBP at 40-70^{th} minute in 10-50^{th} minute post exercise. It therefore concludes that plyometric exercise can reduce SBP for post-exercise hypotension. It could be because the present study used low to moderate intensity plyometric training which leads to greater reduction in SBP.

The finding of the present study also agrees with that of Suleen, et al. (2012) that investigated the effect of moderate intensity resistance, aerobic or combined exercise training on blood pressure and arterial stiffness in overweight and obese individuals. The authors did not observe any significant change in SBP, DBP or augmentation index (AI) between the interventions when assessed the entire cohort, although there were significant improvement in a subgroup of responders. When compared, the two studies used the moderate intensity but the probable reason for this could be that the present study utilised proper plyometric training technique while Suleen et al. used training methods. It could thus be deducted from this study that plyometric training produce lower cardiovascular response than concentric exercise alone (Ankur & Maulik, 2013). These findings suggested that LBPT and UBPT could be used in an overall programme to properly prepare athletes for competition in events that require both aerobic and anaerobic metabolism components.

The findings of the present study is in accordance with Arazi, et al. (2012) that suggested that plyometric exercise increased heart rate, systolic and diastolic blood pressure, and RPP after each set of exercises. Plyometric did not induce any significant changes in muscle soreness. These findings suggested that LBPT and UBPT could be used in an overall training programme to properly prepare university athletes for competitions such as NUGA and NIMSA while it concomitantly promote good healthy lifestyle.

Effect of using lower and upper body plyometric training on DBP.

The result in Table 14 revealed that there was no significant difference in the mean scores of university athletes who were trained using LBPT and UBPT and those in the control. The result in Table 7 revealed that athletes who were trained using LBPT had reduced posttest mean scores 66.25 mmHg better than their counterparts in the control group 70.25 mmHg. The result in Table 10 also showed that athletes who were trained using UBPT had the highest posttest mean scores of DBP 72.38 mmHg not better than their counterparts in the control group 70.25 mmHg. This might be that LBPT is better than the UBPT and could be a better method of training to reduce BP in young athletes.

The probable reason for this highest posttest mean scores of DBP not better than their counterparts in the control group according to Arazi, et al. (2014) could be attributed to the fact that in DBP, no significant changes were observed for low to moderate workload, whereas significant increases were seen at the 10^{th} minute of post-exercise for moderate workload and high workload. The findings showed that the high workload protocol maintained significant increases in the post-exercise DBP until the 20^{th} minute of post-exercise. The findings suggested that coaches and athletes must keep in their minds that high workload of plyometric training induced greater cardiovascular responses and could be a safety way of training which could be proposed to reduce the risk of cardiovascular diseases.

Moreover, Robert (2012) also observed that when blood pressure is measured intra-arterially diastolic blood pressure (DBP) does not change. Diastolic blood pressure remains relatively constant because of peripheral vasodilatation. The present study used blood pressure monitor measured from left which might cause observed high posttest mean scores of DBP of athletes who were trained using LBPT and UBPT. The finding of the present study is in accordance with the views of Bhavna and Sarika (2010) that suggested that repetitive sub maximal strength exercise (eccentric or concentric) is associated with a transient and marked increase in heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure and rate pressure product. The mechanisms responsible for the strength-mediated rise in heart rate and arterial pressure are related to firstly, a transient increase in total systemic vascular resistance associated with performing maximal muscular contractions; and secondly because of neural-mediated mechanisms that stimulate the cardiovascular control centre in the ventro lateral medulla.

Effect of using lower and upper body plyometric training on MAP.

Result in Table 8 revealed that athletes who were trained using lower body plyometric training had posttest mean scores of MAP 78.88 mmHg while their counterparts in the control group had 82.53mmHg. Table11 also revealed that the posttest mean scores of MAP 82.24 mmHg was slightly reduced due to the treatment using UBPT than their counterparts in the control group 82.53mmHg.

Testing of hypothesis three revealed that there was no significant difference in the mean scores of MAP of athletes who were trained using lower and upper body plyometric training and those in the control group (Table 15).

This finding agrees with that of Ankur and Maulik (2013) who suggested that both eccentric and concentric groups improved significantly more improvement was seen in concentric group compared to eccentric group. The result of the study suggests that eccentric exercise produced lower cardiovascular response than concentric exercise. Plyometric training involved three muscular contractions which eccentric comes first immediately followed and by concentric muscle contraction. It utilises the stretch-shortening cycle. Robert (2012) also added that the small rise in systolic blood pressure (SBP) and lack of a significant change in the diastolic blood pressure could cause the mean arterial pressure (MAP) to rise only slightly following the pattern of systolic blood pressure (SBP).

Effect of using lower and upper body plyometric training on RPP

Athletes who were trained using LBPT had reduced posttest mean scores of RPP better than those in the control group (Table 8). Athletes who were trained using UBPT had reduced posttest mean scores of RPP better than those in the control (Fig. 4). Testing the hypothesis five revealed that there was no significant difference in the mean scores of RPP of athletes who were trained using LBPT and UBPT and those in the control group. The reduced RPP posttest mean scores of university athletes could be as a result of reduced HR and SBP, in addition rate pressure product (RPP) is a measure of the stress put on the cardiac muscle based on the number of times it needs to beat per minute (HR) and arterial blood pressure that it is pumping against (SBP).

The finding is in line with Moro, et al. (2013) that expressed that rate pressure product (RPP) is also known as cardiovascular product or double product, is used in cardiology and exercise physiology to determine the myocardial workload. Rate pressure product (RPP) = heart rate (HR) × systolic blood pressure (SBP). However, heart rate and systolic blood pressure rises with activity making them reproducible with exercise, so it’s relatively easy to predict their levels of efficiency.

Effect of using lower and upper body plyometric training on ECG readings

Result in Table 17, 18 and 19 showed that there were no significant differences in the posttest means scores of P-wave, QRS complex and T-wave on ECG readings of athletes who were trained using LBPT and UBPT and those in the control group. Table 17 revealed that the athletes who were trained using LBPT and UBPT had F-calculated value of P wave (0.61 and 0.01) significantly greater than the table value of (0.252 and 0.928) at $p>0.05$ respectively. The result in Table 18 revealed that the F-calculated value of (2.25 and 0.004) were greater than the P-value of QRS complex (0.161 and 0.949) at 0.05 level of significant respectively. Table 19 revealed that the F-calculated value of T wave (1.98 and 0.47) were greater than the P-value of (0.208 and 0.515) at 0.05 level of significant respectively. Analysis of covariance (ANCOVA) indicated lack of significant differences between the LBPT and UBPT and those in the control group in all ECG parameters. This is clarified in Fig. 2 where athletes who were trained using LBPT had the same P and T wave of (.09 and .14) with the control group (.09 and .14) respectively, while QRS complex had (.04) reduced posttest mean better than the control group (.05). Figure 5 also revealed that athletes who were trained using UBPT had the same P and QRS posttest mean scores, while T wave had highest mean scores with the control group.

This finding is in accordance with Bhavna and Sarika (2010) that found out that no significant change was found in ECG parameter after 10 days of eccentric or concentric training. This may be due to inefficient overloading of the cardiac muscles during training or the intensity or duration of training might not be enough to cause left ventricular or cardiac muscle hypertrophy, both of which are depicted in form of ECG interval changes. The improvement in cardiac muscles indicates that adaptation relating to increase in lower and upper body plyometric have occurred. Plyometric training is based upon the principle of overload and specificity. According to the specificity principle, the specific exercise elicits specific adaptations creating specific training effects. This could be attributed to a decrease in cardiac output or systemic vascular resistance. Moreover, the improvement in cardiac muscles indicates that it has been accompanied by a decrease in peripheral sympathetic activity and an increase in cardiac sympathetic activity.

Conclusions

Based on the findings of the study, the following conclusions were made:

The HR mean scores of university athletes who were trained using LBPT and UBPT statistically had reduced significantly better than those in the control group.

Athletes who were trained using LBPT and UBPT have reduced posttest mean scores of SBP better than their counterparts in the control group. Statistically, there was no significant difference in the posttest mean scores of SBP of university athletes who were trained using LBPT, UBPT and those in the control group.

Statistically, there was no significant difference in the posttest mean scores of DBP of university athletes who were trained using LBPT and UBPT and those in the control group.

The use of LBPT and UBPT statistically has no significant difference in the mean scores on MAP of university athletes with those in the control group.

There was no statistically difference in the mean RPP scores of university athletes who were trained using LBPT and UBPT and those in the control group.

Statistically, there were no significant differences in the mean scores of all the parameters (P wave, QRS complex and T wave) on ECG of university athletes who were trained using LBPT and UBPT and those in the control group.

Implications of the Study

The findings of the study have indicated that the use of LBPT and UBPT had reduced the HR, BP and ECG of young university athletes better than those in the control group. It implies that plyometric training will principally improve the explosive abilities of an athlete while it concomitantly promotes good healthy lifestyle. However, proper plyometric training technique is important to fully understand the nature of this type of training. The key mechanisms by which this is achieved include the refinement of an athlete's motor control strategies during the stretch-shortening cycle. It implies that plyometrics are particularly effective when employed with proper techniques by the coaches close to the competitive season.

Athletes should progress gradually from simple plyometric exercises to more intense drills. The intensity and volume of the plyometric should always be comparable to the physiological abilities of the athlete. The emphasis on plyometrics during training should correspond to the goals of the training. It implies that a coach should plan the preparation phase to involve low intensity exercises of longer duration. This will give athletes a base as they move into more intense plyometric drills such as depth jump during the second half of the preparatory phase.

Further, note that it is important therefore that plyometric training sessions should be of high quality. To reap the greatest benefits of plyometric training, the athlete should be fresh enough to perform the movements with a high degree of precision and as explosively as possible. This has implications in terms of the arrangement of the training sessions during the week and for the annual plan. Essentially, the coach should attempt to ensure that where possible plyometrics should be performed when the athlete is fully rested and recovered from previous training sessions.

Similarly, the strength of an athlete will also affect the efficacy of these exercises as training tools. This implies that a stronger athlete is likely to reap greater benefits from high intensity plyometrics than his or her weaker counterparts. It is therefore important to acknowledge that plyometric training can most beneficially be employed by coaches as part of a wider strength and conditioning programme.

Recommendations

Based on the findings of this study and the conclusions drawn, the following recommendations were made:

1. Since the lower and upper body plyometric training have been found to reduce the HR, SBP and DBP of young athletes, there is need for coaches to include both lower and upper body plyometric training as part of athletes' overall training programme from primary to tertiary institutions to maximise performance as well as reduce the risk of cardiovascular diseases and promotes good healthy lifestyle.
2. Coaches and athletes should strive to avoid high intensity exercises during training which could be very dangerous to the functioning of the heart and might lead to athlete's sudden cardiac death or heart attack.
3. University should make effort to organise seminars, workshops, refresher courses for coaches, game masters and game mistresses from primary to secondary school levels in collaborations with strength conditioning professionals such as exercise physiologists, curriculum planners and physiotherapists from higher institutions to modify the existing physical education curriculum.
4. Coaches should understand the implications of cardiovascular responses to training and therefore imbibe a discipline to conduct the pre-exercise screening tests before commencing any sports training to avoid athletes slumping to death on their training pitches.
5. The exercise scientists, physiotherapists and coaches should include plyometric training when prescribing exercises to help people with cardiovascular diseases such as high blood pressure to enable them live a longer and healthier life.

6. Government should provide essential facilities and equipment such ECG, automatic external defibrillators and other cardio emergency equipment to coaches at the training venues at all levels to handle athletes with cardio abnormalities before commencing training to avoid sudden cardiac death.

Limitations of the Study

The subjects were not camped to monitor and control their behaviours at home therefore they may tend to behave mechanically and fake most of their actions which may likely interfere with the dependent variables.

The discrepancies in the BP measurement procedures and instruments may have also affected the outcome of this study. The small size population of twenty-three athletes which may be regarded as not large enough and the athletes in the control group continuing their normal training routine may have also affected the outcome of this study

Suggestions for Further Research

Certain areas not covered by this work provide some bases for future study. These include:

1. Comparative analysis of the effects of lower and upper body plyometric training on metabolic and cardiovascular responses of male and female athletes in any higher institution.

2. Effects of upper body plyometric training on cardiopulmonary response and ECG of male and female athletes in any higher institution.

3. Effects of upper body plyometric training on cardiovascular response and ECG of male and female university athletes on performance of shooting skill in the game of Handball.

4. A comparative study of Bench press and Lat pull on cardiovascular variables and ECG of female Handball and Basketball players in any higher institution.

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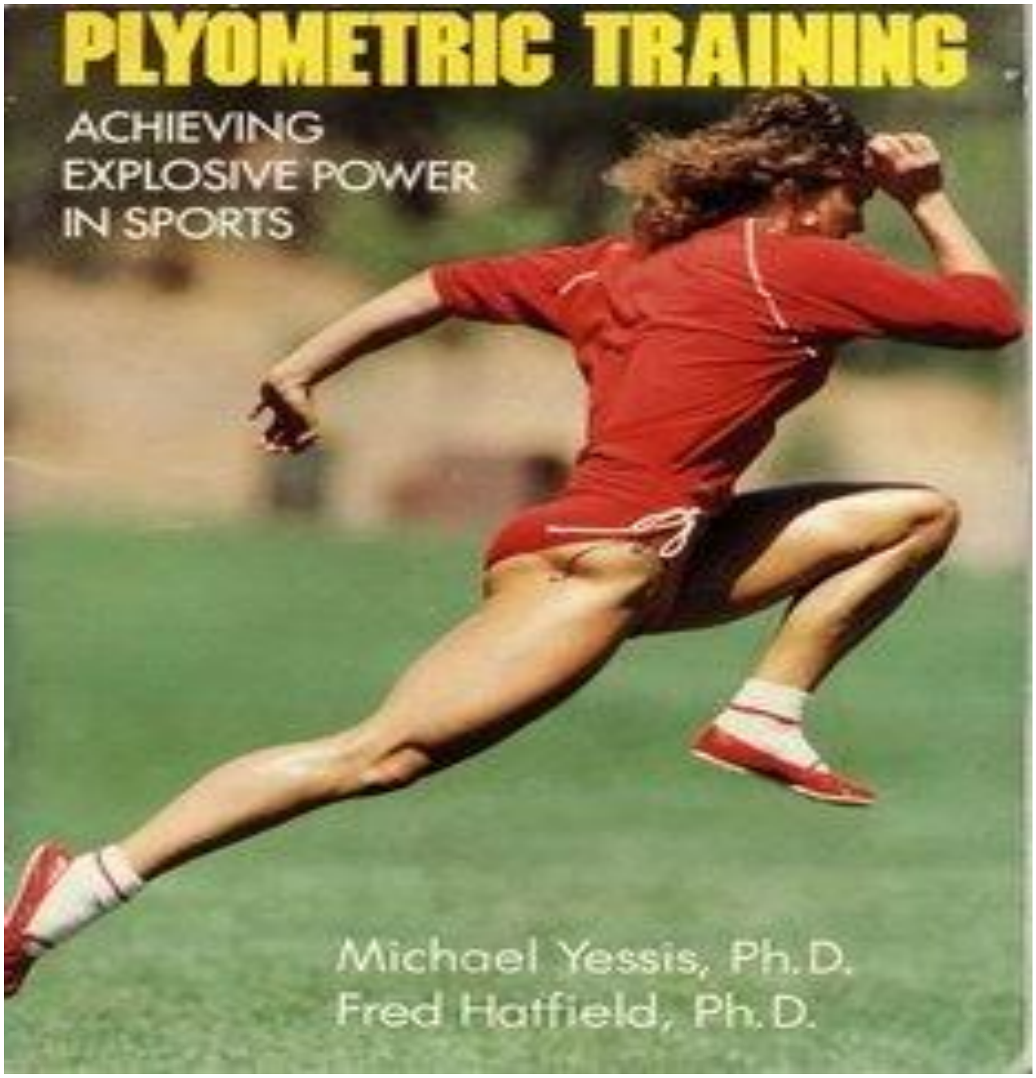
APPENDIX A



PLYOMETRIC TRAINING

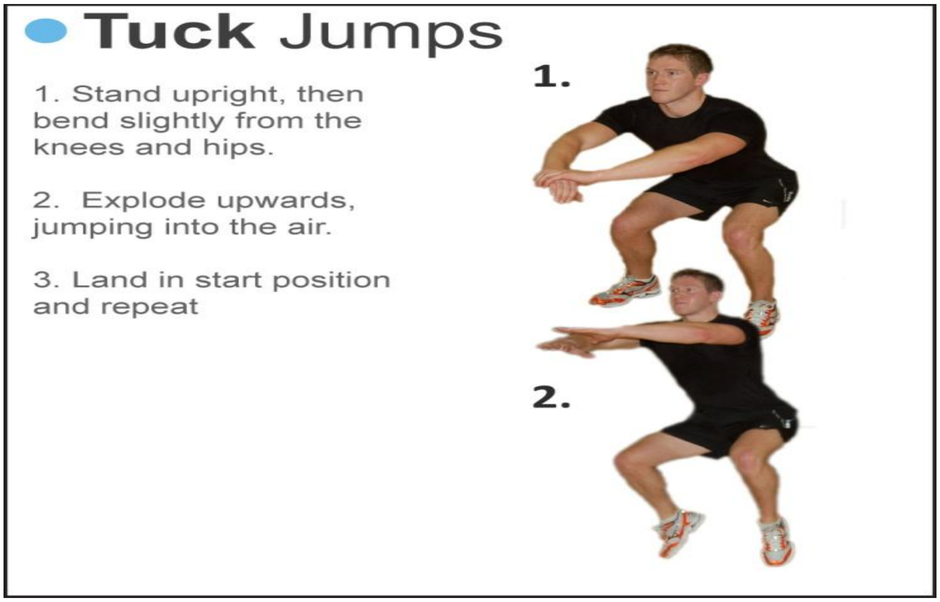
APPENDIX B

Ankle Hops

APPENDIX C

Squat Jumps

APPENDIX D



Tuck Jumps

APPENDIX E

Plyometric Push-ups

APPENDIX *F*

MEDICINE BALL THROW

APPENDIX G

Medicine Ball- Chest Throws

APPENDIX H

SIDE THROW (MEDCINE BALL)

APPENDIX I

OVER HEAD PASS (MEDCINE BALL)

APPENDIX J

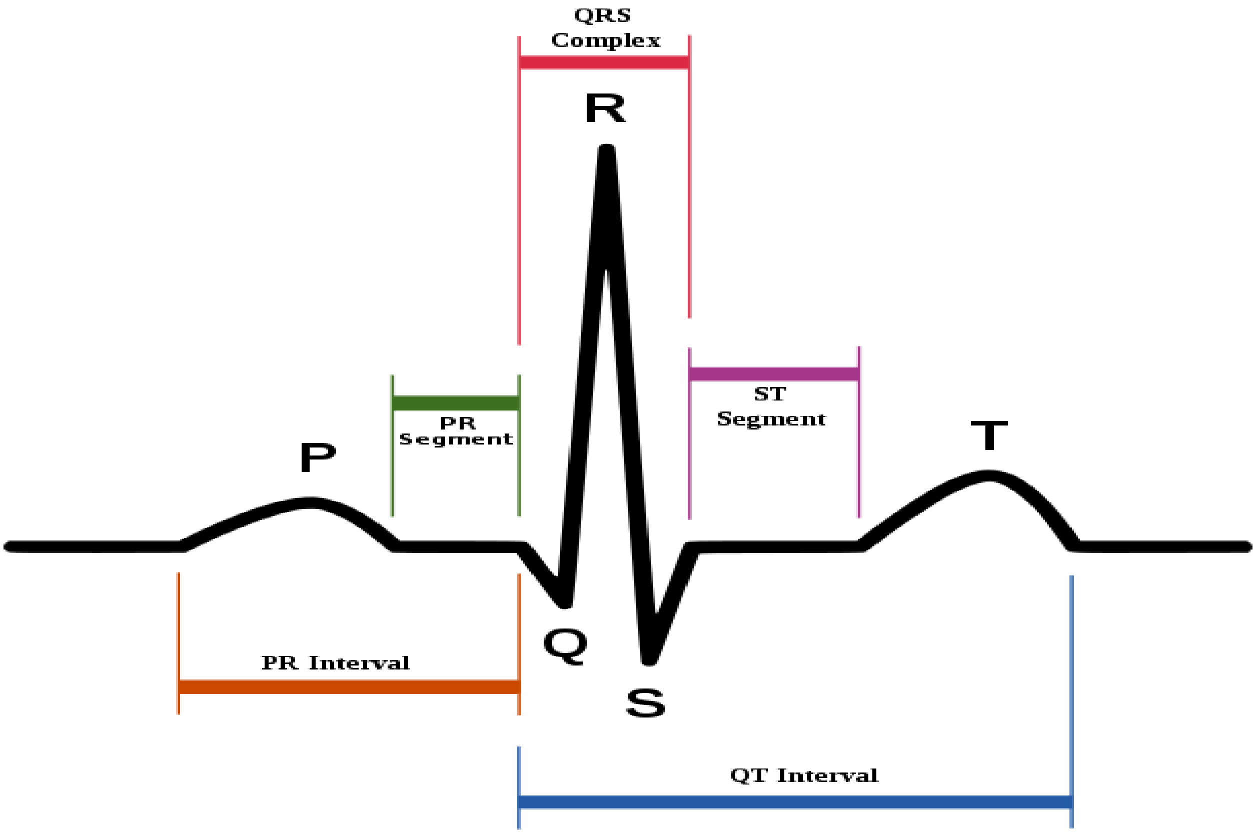
Medicine ball Throws

Medicine ball Throws-Side Throws

APPENDIX K

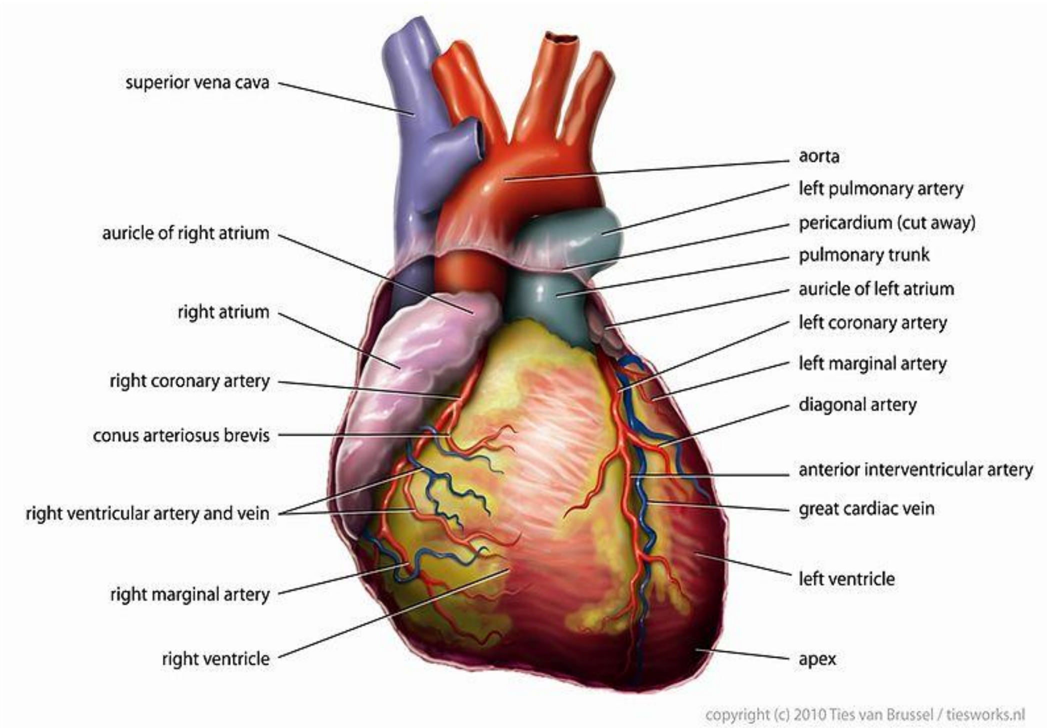
Blood Pressure Monitor

APPENDIX L



A Diagram of Electrocardiogram (Robert, 2012)

APPENDIX N



Anatomy of the Heart (Robert, 2012

APPENDIX O

Age, Weight and Height (BMI) Measurements

LBPT	AGE	WEIGHT	HEIGHT
	20	40	1.59
	18	36	1.70
	19	38	1.68
	20	41	1.69
	19	28	1.55
	20	40	1.58
	24	37	1.70
	23	42	1.72
UBPT	**AGE**	**WEIGHT**	**HEIGHT**
	18	41	1.56
	20	35	1.58
	20	36	1.73
	18	42	1.65
	22	24	1.69
	24	36	1.70
	19	39	1.56
	19	42	1.63
CONTROL	**AGE**	**WEIGHT**	**HEIGHT**
	21	36	1.58
	19	34	1.67
	18	40	1.60
	24	39	1.70
	18	32	1.72
	18	42	1.59
	20	35	1.64
	23	41	1.68

APPENDIX P

	PRETEST					POSTTEST				
	HR	SBP	DBP	MAP		HR	SBP	DBP	MAP	
LBPT	mmHg	mmHg	mmHg	mmHg	RPP	mmHg	mmHg	mmHg	mmHg	RPP
1	80	115	69	84.3	9200	70	102	60	74	7140
2	52	106	78	87.3	5512	48	110	70	83.3	5280
3	56	116	80	92	6496	53	120	64	82.7	6360
4	69	97	68	77.7	6693	54	96	68	77.3	5184
5	67	111	81	91	7437	59	98	60	72.7	5782
6	67	127	91	103	8509	60	98	60	72.7	5880
7	69	97	68	77.7	6693	59	98	70	79.3	5782
8	47	114	76	88.7	5358	48	111	78	89	5328
UBPT										
1	95	120	78	92	11400	53	107	77	87	5671
2	50	100	74	82.7	5000	67	98	70	79.3	6566
3	43	120	65	83.3	5160	44	103	72	82.3	4532
4	63	110	70	83.3	6930	62	110	70	83.3	6820
5	64	105	70	81.7	6720	59	100	75	83.3	5900
6	47	114	76	88.7	5358	49	102	78	86	4998
7	47	103	61	75	4841	56	98	69	78.7	5488
8	64	112	70	84	7168	59	100	68	78	5900
CONTROL										
1	69	107	60	75.7	7383	54	105	65	78.3	5670
2	69	119	81	93.7	8211	53	89	60	69.7	4717
3	66	120	93	102	7920	65	120	90	100	7800
4	65	100	76	84	6500	66	102	80	87.3	6732
5	55	147	63	91	8085	53	113	79	90.3	5989
6	59	116	79	91.3	6844	58	86	71	76	4988
7	73	98	68	78	7154	71	131	52	78.3	9301
8	80	109	81	90.3	8720	72	111	65	80.3	7992

APPENDIX Q

ECG ANALYSIS

	PRETEST				POSTTEST			
		S-T	QRS				QRS	
LBPT	Pwave	sgmt	comp	T wave	P wave	s-T sgmt	comp	T wave
1	0.1	Normal	0.08	0.14	0.1	Normal	0.04	0,12
2	0.1	Normal	0.08	0.14	0.08	Normal	0.04	0.16
3	0.1	Normal	0.08	0.14	0.1	Normal	0.04	0.2
4	0.08	Normal	0.16		0.1	Normal	0.04	0.16
5	0.08	Normal	0.08	0.12	0.1	Normal	0.04	0.16
6	0.1	Normal	0.08	0.12	0.1	Normal	0.04	0.12
7	0.1	Normal	0.06	0.12	0.08	Normal	0.04	0.1
8	0.08	Normal	0.16		0.08	Normal	0.04	0.1
UBPT								
1	0.1	Normal	0.08	0.16	0.08	Normal	0.04	0.1
2	0.08	Normal	0.08	0.12	0.08	Normal	0.06	0.12
3	0.08	Normal	0.1	0.16	0.1	Normal	0.04	0.2
4	0.08	Normal	0.1	0.12	0.08	Normal	0.06	0.16
5	0.1	Normal	0.08	0.16	0.1	Normal	0.06	0.16
6	0.08	Normal	0.08	0.12	0.08	Normal	0.04	0.2
7	0.1	Normal	0.04	0.22	0.08	Normal	0.04	0.24
8	0.1	Normal	0.24		0.1	Normal	0.04	0.16
CONTROL								
1	0.08	Normal	0.16		0.1	Normal	0.04	0.16
2	0.1	Normal	0.08	0.12	0.1	Normal	0.04	0.16
3	0.1	Normal	0.24		0.1	Normal	0.04	0.16
4	0.1	Normal	0.08	O.14	0.08	Normal	0.04	0.12
5	0.1	Normal	0.04	0.2	0.08	Normal	0.04	0.1
6	0.08	Normal	0.16		0.08	Normal	0.08	0.12
7	0.1	Normal	0.08	0.16	0.1	Normal	0.06	0.16