CHAPTER II

REVIEW OF RELATED LITERATURE

In this chapter the literature reviewed on plyometric training swissball training are reviewed. Agarwal (1975) quotes “The literature in any field forms the foundation upon which all future work will be built”. The investigator reviewed the following related literature in this study.

2.1 STUDIES ON EFFECT OF SWISS BALL EXERCISES

Nasnwa Mohnamed (2011) studied on "effect of Using swissball exercises led to positive effect on all variables of motor abilities.on some motor abilities and the level of skill performance of some essential skills in fencing." The result showed that the suggested training programme by using swissball.

Zemkova. et.al (2012) compared the power outputs in concentric phase of chest presses and squats performed in interval mode on stable and unstable surface, respectively. A group of 16 physical education students performed randomly in different days 6 sets of 8 repetitions of a) chest presses on the bench and Swiss ball, respectively, and b) squats on stable support base and Bosuball, respectively with 2 minutes of rest period between sets. The exercises were performed with previously established 70% of 1RM under stable conditions. A PC based system FiTRO Dyne Premium was used to monitor force and velocity and to calculate power. Results showed significantly lower power outputs when resistance exercises were performed on unstable than stable support base. In the initial set, mean power in concentric phase of lifting decreased more profoundly under unstable than stable conditions during both chest presses (13.2% and 7.7%, respectively) and squats (10.3% and 7.2%, respectively). In the final set, the reduction rates of mean power in concentric phase of chest presses were significantly ($p<.05$) greater on Swiss ball than on the bench (19.9% and 11.8%, respectively). On the other hand, there were no significant differences in decline of power in concentric phase of squats on Bosu ball and on stable support base (11.4% and 9.6%, respectively). It may be concluded that power outputs during resistance exercises is more profoundly compromised under unstable than stable conditions, and this effect is more evident for barbell chest presses on Swiss ball than for barbell squats on Bosu ball. These findings have to be taken into account when instability resistance exercises are implemented into the training program, namely for sports that require production of maximal force in short time.

Saeterbakken (2012) demonstrated on "Electromyography activity and 6-RM strength in bench press on stable and unstable surfaces". The purpose of the study was to compare six repetition maximum (6-RM) loads and muscle activity in bench press on three surfaces, namely stable bench, balance cushion and swissball.16 healthy, resistance trained males (age 22.5-2.0 years, stature 1.82-6.6 m, and body mass 82.0-7.8 kg) volunteered for three habituation/strength testing sessions, and one experimental session. In randomized order on the three surfaces, 6-RM strength and electromyographic activity of pectoralis major, deltoid anterior, biceps brachii, triceps brachii, rectus abdominis, oblique external and erector spinae were assessed. Relative to stable bench, the 6-RM strength was 93% for balance cushion and 92% for swissball the pectoralis major EMG activity was 90% using the balance cushion (P=0.080) and 81% using swissball (P=0.006) the triceps EMG was 79% using the balance cushion (P=0.028) and 69% using the swissball (P=0.002). Relative to balance cushion, the EMG activity in pectoralis, triceps and erector spinae using swissball was 89% (P=0.016), 88% (P=0.014) and 80% (P=0.020), respectively. In rectus abdominis, the EMG activity relative to swissball was 69% using stable bench (P=0.042) and 65% using the balance cushion (P=0.046). Similar EMG activities between stable and unstable surfaces were observed for deltoid anterior, biceps brachii and oblique external. In conclusion, stable bench press had greater 6-RM strength and triceps and pectoralis EMG activity compared t the unstable surfaces. These findings have implications for athletic training and rehabilitation, as they demonstrate an inferior effect of unstable surfaces on muscle activation of prime movers and strength in bench press. If an unstable surface in bench press is desirable, a balance cushion should be chosen instead of a swissball.

Sekendiz et.al (2011) studied the effects of Swiss-ball core strength training on strength, endurance, flexibility, and balance in sedentary women The purpose of this study was to investigate the effects of Swiss-ball core strength training on trunk extensor (abdominal)/flexor (lower back) and lower limb extensor (quadriceps)/flexor (hamstring) muscular strength, abdominal, lower back and leg endurance, flexibility and dynamic balance in sedentary women (n = 21; age = 34 ± 8.09; height = 1.63 ± 6.91 cm; weight = 64 ± 8.69 kg) trained for 45 minutes, 3 d·wk-1 for 12 weeks. Results of multivariate analysis revealed significant difference ($p \leq 0.05$) between pre and postmeasures of 60 and 90° s trunk flexion/extension, 60 and 240° s-1 lower limb flexion/extension (Biodex Isokinetic Dynamometer), abdominal endurance (curl-up test), lower back muscular endurance (modified Sorensen test), lower limb endurance (repetitive squat test), lower back flexibility (sit and reach test), and dynamic balance (functional reach test). The results support the fact that Swiss-ball core strength training exercises can be used to provide improvement in the aforementioned measures in sedentary women. In conclusion, this study provides practical implications for sedentary individuals, physiotherapists, strength and conditioning specialists who can benefit from core strength training with Swiss balls.

Korkusuz et.al (2011) studied the effects of Swiss-ball core strength training on strength, endurance, flexibility, and balance in sedentary women The purpose of this study was to investigate the effects of Swiss-ball core strength training on trunk extensor (abdominal)/flexor (lower back) and lower limb extensor (quadriceps)/flexor (hamstring) muscular strength, abdominal, lower back and leg endurance, flexibility and dynamic balance in sedentary women ($n = 21$; age = 34 ± 8.09; height = 1.63 ± 6.91 cm; weight = 64 ± 8.69 kg) trained for 45 minutes, 3 d·wk-1 for 12 weeks. Results of multivariate analysis revealed significant difference ($p \leq 0.05$) between pre and postmeasures of 60 and 90° s trunk flexion/extension, 60 and 240° s-1 lower limb flexion/extension (Biodex Isokinetic Dynamometer), abdominal endurance (curl-up test), lower back muscular endurance (modified Sorensen test), lower limb endurance (repetitive squat test), lower back flexibility (sit and reach test), and dynamic balance (functional reach test). The results support the fact that Swiss-ball core strength training exercises can be used to provide improvement in the aforementioned measures in sedentary women. In conclusion, this study provides practical implications for sedentary individuals, physiotherapists, strength and conditioning specialists who can benefit from core strength training with Swiss balls.

Araujo et.al (2011) studied on "Shoulder muscular activity during isometric three-point kneeling exercise on stable and unstable surfaces" The purpose study was to determine if performing isometric 3-point kneeling exercises on a Swiss ball influenced the isometric force output and EMG activities of the shoulder muscles when compared with performing the same exercises on a stable base of support. Twenty healthy adults performed the isometric 3-point kneeling exercises with the hand placed either on a stable surface or on a Swiss ball. Surface EMG was recorded from the posterior deltoid, pectoralis major, biceps brachii, triceps brachii, upper trapezius, and serratus anterior muscles using surface differential electrodes. All EMG data were reported as percentages of the average root mean square (RMS) values obtained in maximum voluntary contractions for each muscle studied. The highest load value was obtained during exercise on a stable surface. A significant increase was observed in the activation of glenohumeral muscles during exercises on a Swiss ball. However, there were no differences in EMG activities of the scapulothoracic muscles. These results suggest that exercises performed on unstable surfaces may provide muscular activity levels similar to those performed on stable surfaces, without the need to apply greater external loads to the musculoskeletal system. Therefore, exercises on unstable surfaces may be useful during the process of tissue regeneration.

Kimberly (2005) conducted a study to assess the outcome of a five-week core stabilization training program on dynamic balance. The study was a 2x2 factorial design with an experimental and control group. This study included 13 healthy physically active collegiate level tennis athletes and 15 subjects in the control group of aged matched activity cohorts. The five-week protocol for the core stabilization-training program was conducted as follows: subjects followed the program 3 times a week for an average of 30-minute sessions. There were 3 progressive levels of exercises focusing on strengthening the core while maintaining neuromuscular control. All subjects chosen for the study completed a pre and post-test measurement of their dynamic balance using the Star Excursion Balance Test (SEBT). The test was conducted one week prior to and following the five-week exercise protocol. A significant difference for time was found for pre-test and post-test within subjects for all eight excursions (anterior, anteromedial, medial, poster medial, posterior, poster lateral, lateral, anterolateral). There were no significant main effects for Group or interaction between Time and Group. In conclusion, Core stabilization-training may be used to enhance dynamic balance in tennis athletes.

Marshall (2010) studied on "Electromyography analysis of upper body, lower body, and abdominal muscles during advanced Swiss ball exercises". The purpose of his study was to determine whether or not muscle activity measured during advanced Swiss ball exercises was at an approximate intensity ecommended for strength or endurance training in advanced, or novice individuals. After a miliarization session, 14 recreationally active subjects performed 6 different advanced" Swiss ball exercises in a randomized order. The primary dependent variables in this study were the activity levels collected from anterior deltoid, pectoralis major, rectus abdominis (RA), external obliques, lumbar erector spinae, vastus lateralis (VL), and biceps femoris using surface electromyography. All signals were normalized to maximal voluntary isometric contractions performed before testing for each muscle. The results of the study showed that the Swiss ball roll elicited muscle activity in triceps brachii (72.5+/-32.4%) and VL (83.6+/-44.2%) commensurate with the intensity recommended for strength exercises in advanced trainers. Rectus abdominis activity was greatest during the bridge exercise (61.3+/-28.5%, p<or=0.01). This was the only exercise to elicit RA muscle activity commensurate with a strength training effect. The remainder of the exercises elicited abdominal activity that would require a higher number of repetitions to be performed for an endurance training adaptation. Although this study has provided evidence for one advanced Swiss ball exercise providing a significant whole-body stimulus, the practical difficulty and risks of performing these more complicated Swiss ball exercises may outweigh potential benefits.

Escamilla et.al (2010) conducted a study to find out the ability of 8 Swiss ball exercises (roll-out, pike, knee-up, skier, hip extension right, hip extension left, decline push-up, and sitting march right) and 2 traditional abdominal exercises (crunch and bent-knee sit-up) on activating core (lumbopelvic hip complex) musculature.Numerous Swiss ball abdominal exercises are employed for core muscle strengthening during training and rehabilitation, but there are minimal data to substantiate the ability of these exercises to recruit core muscles. It is also unknown how core muscle recruitment in many of these Swiss ball exercises compares to core muscle recruitment in traditional abdominal exercises such as the crunch and bent-knee sit-up. A convenience sample of 18 subjects performed 5 repetitions for each exercise. Electromyographic (EMG) data were recorded on the right side for upper and lower rectus abdominis, external and internal oblique, latissimus dorsi, lumbar paraspinals, and rectus femoris, and then normalized using maximum voluntary isometric contractions (MVICs). EMG signals during the roll-out and pike exercises for the upper rectus abdominis (63% and 46% MVIC, respectively), lower rectus abdominis (53% and 55% MVIC, respectively), external oblique (46% and 84% MVIC, respectively), and internal oblique (46% and 56% MVIC, respectively) were significantly greater compared to most other exercises, where EMG signals ranged between 7% to 53% MVIC for the upper rectus abdominis, 7% to 44% MVIC for the lower rectus abdominis, 14% to 73% MVIC for the external oblique, and 16% to 47% MVIC for the internal oblique. The lowest EMG signals were consistently found in the sitting march right exercise. Latissimus dorsi EMG signals were greatest in the pike, knee-up, skier, hip extension right and left, and decline push-up (17%-25% MVIC), and least with the sitting march right, crunch, and bent-knee sit-up exercises (7%-8% MVIC). Rectus femoris EMG signal was greatest with the hip extension left exercise (35% MVIC), and least with the crunch, roll-out, hip extension right, and decline push-up exercises (6%-10% MVIC). Lumbar paraspinal EMG signal was relative low (less than 10% MVIC) for all exercises. The roll-out and pike were the most effective exercises in activating upper and lower rectus abdominis, external and internal obliques, and latissimus dorsi muscles.

Rafael et.al (2010) estimated the **"**Core Muscle Activation during Swiss Ball and Traditional Abdominal Exercises". To test the ability of 8 Swiss ball exercises (roll-out, pike, knee-up, skier, hip extension right, hip extension left, decline push-up, and sitting march right) and 2 traditional abdominal exercises (crunch and bent-knee sit-up) on activating core (lumbopelvic hip complex) musculature: Numerous Swiss ball abdominal exercises are employed for core muscle strengthening during training and rehabilitation, but there are minimal data to substantiate the ability of these exercises to recruit core muscles. It is also unknown how core muscle recruitment in many of these Swiss ball exercises compares to core muscle recruitment in traditional abdominal exercises such as the crunch and bent-knee sit-up. A convenience sample of 18 subjects performed 5 repetitions for each exercise. Electromyographic (EMG) data were recorded on the right side for upper and lower rectus abdominis, external and internal oblique, latissimus dorsi, lumbar paraspinals, and rectus femoris, and then normalized using maximum voluntary isometric contractions (MVICs). EMG signals during the roll-out and pike exercises for the upper rectus abdominis (63% and 46% MVIC, respectively), lower rectus abdominis (53% and 55% MVIC, respectively), external oblique (46% and 84% MVIC, respectively), and internal oblique (46% and 56% MVIC, respectively) were significantly greater compared to most other exercises, where EMG signals ranged between 7% to 53% MVIC for the upper rectus abdominis, 7% to 44% MVIC for the lower rectus abdominis, 14% to 73% MVIC for the external oblique, and 16% to 47% MVIC for the internal oblique. The lowest EMG signals were consistently found in the sitting march right exercise. Latissimus dorsi EMG signals were greatest in the pike, knee-up, skier, hip extension right and left, and decline push-up (17%-25% MVIC), and least with the sitting march right, crunch, and bent-knee sit-up exercises (7%-8% MVIC). Rectus femoris EMG signal was greatest with the hip extension left exercise (35% MVIC), and least with the crunch, roll-out, hip extension right, and decline push-up exercises (6%-10% MVIC). Lumbar paraspinal EMG signal was relative low (less than 10% MVIC) for all exercises. It was concluded that the roll-out and pike were the most effective exercises in activating upper and lower rectus abdominis, external and internal obliques, and latissimus dorsi muscles, while minimizing lumbar paraspinals and rectus femoris activity.

Betul Sekendiz (2010) conducted a study on the "effects of Swiss-ball core strength training on strength, endurance, flexibility, and balance in sedentary women". The study was to investigate the effects of Swiss-ball core strength training on trunk extensor (abdominal)/flexor (lower back) and lower limb extensor (quadriceps)/flexor (hamstring) muscular strength, abdominal, lower back and leg endurance, flexibility and dynamic balance in sedentary women (n = 21; age = 34 ± 8.09; height = 1.63 ± 6.91 cm; weight = 64 ± 8.69 kg) trained for 45 minutes, 3 d·wk-1 for 12 weeks. Results of multivariate analysis revealed significant difference ($p = 0.05$) between pre and post measures of 60 and 90° s-1 trunk flexion/extension, 60 and 240° s-1 lower limb flexion/extension (Biodex Isokinetic Dynamometer), abdominal endurance (curl-up test), lower back muscular endurance (modified Sorensen test), lower limb endurance (repetitive squat test), lower back flexibility (sit and reach test), and dynamic balance (functional reach test). The results support the fact that Swiss-ball core strength training exercises can be used to provide improvement in the aforementioned measures in sedentary women. In conclusion, this study provides practical implications for sedentary individuals, physiotherapists, strength and conditioning specialists who can benefit from core strength training with Swiss balls.

Whiting et.al (2010). In their study an exercise programs have been designed to integrate training of the trunk muscles with training of the extremities. Many believe that the most effective way to recruit the core stabilizing muscles is to execute traditional exercise movements on unstable surfaces. However, physical activity is rarely performed with a stable load on an unstable surface; usually, the surface is stable, and the external resistance is not. The purpose of this study was to evaluate muscle activity of the prime movers and core stabilizers while lifting stable and unstable loads on stable and unstable surfaces during the seated overhead shoulder press exercise. Thirty resistance-trained subjects performed the shoulder press exercise for 3 sets of 3 repetitions under 2 load (barbell and dumbbell) and 2 surface (exercise bench and Swiss ball) conditions at a 10 repetition maximum relative intensity. Surface electromyography (EMG) measured muscle activity for 8 muscles (anterior deltoid, middle deltoid, trapezius, triceps brachii, rectus abdominis, external obliques, and upper and lower erector spinae). The average root mean square of the EMG signal was calculated for each condition. The results showed that as the instability of the exercise condition increased, the external load decreased. Triceps activation increased with external resistance, where the barbell/bench condition had the greatest EMG activation and the dumbbell/Swiss ball condition had the least. The upper erector spinae had greater muscle activation when performing the barbell presses on the Swiss ball vs. the bench. The findings provide little support for training with a lighter load using unstable loads or unstable surfaces.

Hildenbrank and Noble (2000) conducted a study on “Abdominal Muscle Activity While Performing Trun Flexion Exercises Using the Ab Roller, Abslides, Fitball and Conventionally Performed Trunk Curls”, to compare the surface electromyo graphic activity of the abdominal musculature and rectus femoris (RF) muscle during trunk-flexion exercises using 3 abdominal exercise devices (Ab Roller, ABslide, and FitBall) and the traditional trunk curl. Each subject performed approximately 15 repetitions for each exercise condition. A repeated-measures, one-way multivariate analysis of variance was used to compare the mean integrated electric activity value for each muscle during each exercise condition. A total of 10 male and 13 female collegiate undergraduate students. Surface electromyo graphic activity was recorded for the upper rectus abdominis (URA), lower rectus abdominis (LRA), external oblique (EO), and RF during 5 consecutive repetitions of each exercise bout. The signal was amplified by a factor of 1000, rectified, and integrated. These integrated values were then divided by the time value for each exercise to give the mean integrated electromyography value. A significant difference existed among exercise conditions for the RF, with the ABslide and the FitBall having greater electric activity than the other exercise conditions. Activity was significantly different for the URA, with the ABslide having the least electric activity. For the EO, exercising with the ABslide produced significantly greater electric activity than all other exercise conditions. No significant difference was found across exercise conditions for the LRA Performing abdominal exercises with the Ab Roller, ABslide, and FitBall did not elicit greater activity of the URA and LRA than performing traditional trunk curls. Use of the ABslide elicited greater EO activity and significantly less URA activity than the other 3 modes. Both the ABslide and FitBall resulted in greater involvement of the hip flexors, an undesirable feature of abdominal exercises.

Stanton et al (2004) conducted a study on “The effect of short term Swiss ball Training on core stability and running economy”. The purpose of this study was to investigate the effect of a short-term Swiss ball training on core stability and running economy. Eighteen young male athletes (15.5 +/- 1.4 years; 62.5 +/- 4.7 kg; sigma9 skinfolds 78.9 +/- 28.2 mm; $V0_2$ max 55.3 +/- 5.7 ml.kg(-l),min(-l)) were divided into a control (n = 10) and experimental (n = 8) groups. Athletes were assessed before and after the training program for stature, body mass, core stability, electromyographic activity of the abdominal and back muscles, treadmill $V0_2$ max, running economy, and running posture. The experimental group performed 2 Swiss ball training sessions per week for 6 weeks. Data analysis revealed a significant effect of Swiss ball training on core stability in the experimental group ($p < 0.05$). No significant differences were observed for myoelectric activity of the abdominal and back muscles, treadmill $V0_2$ max, running economy, or running posture in either group. It appears Swiss ball training may positively affect core stability without concomitant improvements in physical performance in young athletes. Specificity of exercise selection should be considered.

Lehman et al. (2005) conducted a study on "Trunk muscle activity during bridging exercises on and off a swissball". The study was to determine whether the addition of a swiss ball to trunk bridging exercises influences trunk muscle activity. The method adopted for testing was surface electrodes recorded the myoelectric activity of trunk muscles during bridging exercises. The results obtained during the prone bridge the addition of an exercise ball resulted in increased myoelectric activity in the rectus abdomens and external oblique. The internal oblique and erector spinae were not influenced. The addition of a swiss ball during supine bridging did not influence trunk muscle activity for any muscles studied. Thus the investigator concluded that modifying common bridging exercises can influence the amount of trunk muscle activity, suggesting that exercise routines can be designed to maximize or minimize trunk muscle exertion depending on the needs of the exercise population.

Lehman et al. (2005) conducted a study on "Replacing a swiss ball for an exercise bench causes variable changes in trunk muscle activity during upper limb strength exercises". The aim of the study was to determine whether the addition of a swiss ball to upper body strength exercises results in consistent increase in trunk muscle activation levels. The methodology for the study was the myocletric activity of four trunk muscle was quantified during the performance of upper body resistance exercises while scatted on both a stable (exercise bench) and lable (swiss ball) furface. Training implemented for the study are the supine chest press, shoulder press, lateral raise, biceps curl and overhead triceps extension. Statistics applied for the study was a repeated measures ANOVA with post hoc Tukey test. There was no statistically significant ($p<0.05$) difference in muscle activity between surface conditions. However, there was large degree of varsality across subjects suggesting that some individuals respond differently to surface stability. Thus the researcher conducted that selected trunk muscle activity during certain upper limb strength training exercises is not consistently influenced by the replacement of an exercise bench with a swiss ball.

Marshall and Murphy (2005) conducted a study on core stability exercises on and off a swiss ball at department of sports and exercise science, University of Auckland, New Zealand. The objectives for the study are to assess lumbopelvic muscle activity during different core stability exercises on and off a Swiss ball. In this study eight healthy volunteers from a University population were used. Subjects performed 4 exercises on and off a Swiss ball: inclined press up, upper body roll out, single leg hold and quadruped exercises. Main outcome measures are surface electromyography from selected lumbopelvic muscles normalized to maximum voluntary isometric contraction, and median frequency analysis of electromyography power spectrum visual analog scale for perception of task difficulty. Results obtained were a significant increase in the activation of the rettus abdominus with performance of a single leg hold and at the top of the press up on the Swiss ball. This led to changes in the relation between the activation levels of the lumbopelvic muscles measure.

Goodman, et.al. (2008) documented that exercise or Swiss balls are increasingly being used with conventional resistance exercises. There is little evidence supporting the efficacy of this approach compared to traditional resistance training on a stable surface. Previous studies have shown that force output may be reduced with no change in muscle electromyography (EMG) activity while others have shown increased muscle EMG activity when performing resistance exercises on an unstable surface. This study compared 1RM strength, and upper body and trunk muscle EMG activity during the barbell chest press exercise on a stable (flat bench) and unstable surface (exercise ball). After familiarization, 13 subjects underwent testing for 1RM strength for the barbell chest press on both a stable bench and an exercise ball, each separated by at least 7 days. Surface EMG was recorded for 5 upper body muscles and one trunk muscle from which average root mean square of the muscle activity was calculated for the whole 1RM lift and the concentric and eccentric phases. Elbow angle during each lift was recorded to examine any range-of-motion differences between the two surfaces. The results show that there was no difference in 1RM strength or muscle EMG activity for the stable and unstable surfaces. In addition, there was no difference in elbow range-of-motion between the two surfaces. Taken together, these results indicate that there is no reduction in 1RM strength or any differences in muscle EMG activity for the barbell chest press exercise on an unstable exercise ball when compared to a stable flat surface. Moreover, these results do not support the notion that resistance exercises performed on an exercise ball are more efficacious than traditional stable exercises.

Willardson. (2007) found that in recent years, fitness practitioners have increasingly recommended core stability exercises in sports conditioning programs. Greater core stability may benefit sports performance by providing a foundation for greater force production in the upper and lower extremities. Traditional resistance exercises have been modified to emphasize core stability. Such modifications have included performing exercises on unstable rather than stable surfaces, performing exercises while standing rather than seated, performing exercises with free weights rather than machines, and performing exercises unilaterally rather than bilaterally. Despite the popularity of core stability training, relatively little scientific research has been conducted to demonstrate the benefits for healthy athletes. Therefore, the purpose of this review was to critically examine core stability training and other issues related to this topic to determine useful applications for sports conditioning programs. Based on the current literature, prescription of core stability exercises should vary based on the phase of training and the health status of the athlete. During preseason and in-season mesocycles, free weight exercises performed while standing on a stable surface are recommended for increases in core strength and power. Free weight exercises performed in this manner are specific to the core stability requirements of sports-related skills due to moderate levels of instability and high levels of force production. Conversely, during postseason and off-season mesocycles, Swissball exercises involving isometric muscle actions, small loads, and long tension times are recommended for increases in core endurance. Furthermore, balance board and stability disc exercises, performed in conjunction with plyometric exercises, are recommended to improve proprioceptive and reactive capabilities, which may reduce the likelihood of lower extremity injuries.

Georgios Kipreos et.al. (2010) documented that coronary arteries are subjected daily in high shear stress and manifest atherosclerosis very early in life in comparison to other arteries in the human body. Some factors that are implicated in the evolution and progress of this process are the concentration of lipids and arachidonic acid metabolites, such prostacyclin and thromboxane. It has been reported that those who participate in aerobic activities such as walking, cycling, jogging or brisk walking might have normal values of the mentioned chemical substances. On the other hand, it is reported that the effects of anaerobic and strength activities has negative effects on the vascular endothelium, which is essential for the maintenance of hemostatic balance and the local regulation of vascular tone. Therefore, even although extensive research has been conducted in this field, there are crucial gaps in our knowledge. Consequently, the purpose of this brief review is to describe what is known about the effects of anaerobic activities in which the competitive athletes have participated on the following blood parameters: Total cholesterol, triglycerides, high density lipoprotein cholesterol (HDL - C), low density lipoproteins cholesterol (LDL - C), prostacyclin & thromboxane

Baljinder Singh Bal et. al. (2012) investigated the effects of 6 week plyometric training on biochemical and physical fitness parameters of inter collegiate jumpers. A group of 30 jumpers (mean ± SD: age 22.02 ± 1.64 years, height 1.78 ± 0.04 m, body mass 75.5 ± 5.2 kg), who participated in inter-college athletic competition volunteered to participate in this study. The study was approved by the Ethics Committee of Directorate of Sport in Guru Nanak Dev University, Amritsar, India. All participants were informed about the study aim and methodology. All the subjects agreed to the above conditions in writing. They were randomly assigned into plyometric training (P) and control (C) groups, n=15 each. Plyometric group (P) was subjected to 6 week plyometric training program of 30 min a day and the control group did not perform any plyometric training techniques. The following biochemical and physical fitness parameters were determined: haemoglobin (g.dl-1), urea (mg.dl-1), uric acid (mg.dl-1), total cholesterol (mg.dl-1), triglyceride (mg.dl-1), aerobic capacity, body composition and trunk strength and endurance. A paired (samples) t-test was used in data analysis. The level of p£0.05 was considered significant. Significant between-group differences were found in aerobic capacity (t=2.40*), body composition (t=2.43*) and abdominal strength and endurance (t=2.96*) whereas no significant between-group differences were noted in haemoglobin (t=1.25), urea (t=1.14), uric acid (t=1.10), total cholesterol (t=1.61) and triglyceride (t=1.56).The plyometric training may be recommended to improve and maintain physical fitness parameters of Jumpers.

Tofas T, et.al. (2008) examined the effect of acute plyometric exercise on indices of muscle damage and collagen breakdown. Nine untrained men performed an intense bout of plyometric jumping exercises (experimental group) and nine men remained at rest (control group). Seven days before and 24, 48, and 72 hours after plyometric exercise or rest, several physiological and biochemical indices of muscle damage and two biochemical indices of collagen damage were determined. No significant changes in concentric and eccentric peak torque of knee extensors and flexors or flexion and extension range of motion were found after the plyometric exercise. Delayed-onset muscle soreness increased 48 hours after exercise. Creatine kinase increased 48 and 72 hours post exercise, whereas lactate dehydrogenase increased 24, 48, and 72 hours post exercise. Serum hydroxyproline increased 24 hours post exercise, peaked at 48 hours, and remained elevated up to 72 hours post exercise. Hydroxylysine (which was measured only before exercise and at 48 hours) was found increased 48 hours post exercise. No differences were found in any physiological or biochemical index in the control group. Intense plyometric exercise increased muscle damage, delayed-onset muscle soreness, and serum indices of collagen breakdown without a concomitant decrease in the functional capacity of muscles. Hydroxyproline and hydroxylysine levels in serum seem promising measures for describing exercise-induced collagen degradation. Coaches need to keep in mind that by using plyometric activities, despite the increased muscle damage and collagen turnover that follow, it is not necessarily accompanied by decreases in skeletal muscle capacity.

Subramanian and Venkatesan (2012) selected 50 male Type 2 diabetic subjects between 30 – 60 years have participated in the study. Subjects were recruited through diabetic camps organized during July 2010, through advertisements given in regional English news paper, The Hindu, and Velachery Times. All the subjects were tested on two occasions by using same protocols. Baseline measurements were taken before the intervention and after the study again. Venous blood sample of all participants were taken for analysis of Lipid profile and Glycelated Haemoglobin. Having done the exercises for three times per week, each exercise session comprising of ten different exercises for major muscle groups of Lower extremities including Gluteus maximus, Quadriceps femoris, Hamstrings, Gastrocnemius, Abdominal muscles, Lumbar spine extensors. This study showed following Stability Ball Exercises significant improvement in Glycelated Haemoglobin, Lipid profile and Body mass index among male Type 2 diabetic patients. Exercises accelerate more insulin absorption from the leg, than arm exercises. 1% decrement in Glycelated haemoglobin following therapies to lower Glycelated haemoglobin can reduce the risk of diabetic complications such as myocardial infarction and microvascular disease. A better glucose control due to improvement in insulin sensitivity and effects of glucose transporters due to muscular hypertrophy and blood flow following resisted exercises.In this study 0.69% reduction in Glycelated haemoglobin among the post mean score value, hence is effective for better glycaemic control. Exercises lowers the risk of death by up to 25% in coronary heart disease patients, and the benefits include decreased Total Cholesterol, LDL, and an increased HDL. A single bout of moderate exercise will increase after exercise regardless of training or intensity.

Jerrold S. Petrofsky (2007) examined to determine muscle use that occurred during core body exercise using a 7-inch diameter mini stability ball produced by Savvier LP (Santa Fe Springs, Ca) compared with abdominal crunches on the floor and on a Swiss ball. Muscle use was evaluated through the surface electromyogram recorded above the abdominal and lower back muscles. Three levels of core exercise were tested with the mini stability ball. The results showed that crunches on the Swiss ball used approximately 50% more muscle work per second of exercise as did work with the floor crunches.The lightest exercise (sitting crunches with the mini stability ball behind the back) was about equal to half of the work per second as floor crunches. However, the most intense exercises with the mini ball were as much as 4 times the work as abdominal crunches per second of exercise. The greatest difference in the mini stability ball exercise was seen when the degree of flexion/extension was increased from 50 to 90 degrees.This degree of flexion cannot be accomplished with standard floor crunches or with the Swiss ball (due to its larger diameter and size), thereby giving the mini stability ball a significant advantage in working the muscles harder and at a better range of motion.

Yüksel Savucu et.al. (2011) searched the impact of quick strength and aerobic endurance trainings on forty male amateur footballer's some blood lipid parameters. Before the new season, first measurements were done by taking their bloods. Then quick strength training was applied a day in a week and other a day aerobics endurance training was applied to 40 footballers (mean=20.88 ± 2.68 years) with regular football training for 5 months. At the end of regular trainings for five months, second measurements were done by taking their blood samples to compare with the impacts of quick strength and aerobics endurance training on male amateur footballer's blood lipid profile. The statistical software package program was used to evaluation of statically analyses and received their modifications in the pre-test and post-test comparison of paired Student's t test in level of $p<0.01$. Data are summarized by calculating the average standard deviation, t and p values. As a result, it had been shown that quick strength and aerobics endurance trainings for 20 weeks change footballer's blood lipid profiles and body compositions positively.

The link between cholesterol and CHD has been fairly well established through long-term studies of individuals with high levels of blood cholesterol and the incidence of CHD. As high-density lipoprotein cholesterol (HDL-C) (good cholesterol) levels increase, they are independently associated with lower risk of CHD (Neiman 2003) . It is also well established that a sedentary lifestyle contributes significantly to the development of CHD and to unfavorable elevation of blood fats and cholesterol levels; physical activity plays an important role in decreasing these health risks.

The exercise thresholds established from longitudinal and cross-sectional training studies indicate that 15–20 miles per week of jogging or brisk walking, which is equivalent to 1,200–2,200 kilocalories of energy expenditure, may decrease blood triglycerides by 5–38 milligrams per deciliter (mg/dl) (Durstine et al. 2002) . That same threshold of exercise (15–20 miles per week of jogging or brisk walking) has been shown to elevate HDL-C (a positive alteration) by 2–8 mg/dl. Durstine and colleagues further conclude that exercise training studies rarely show a decrease in total cholesterol or LDL-C (the bad cholesterol), unless there is a loss of body weight or a decrease in dietary fat (or both). The serum level of LDL-C has been shown to be significantly reduced among women (a decrease of 14.5±–22.2 mg/dl) and men (a decrease of 20.0±–17.3 mg/dl) randomly assigned to a diet-plus-exercise group, as compared to a control group (women had a decrease of 2.5±–16.6 mg/dl; men had a decrease of 4.6±–21.1 mg/dl) (Stefanick et al. 1998).

Although some studies have shown a favorable impact of resistance training on blood lipids, others have reported no change. It may be that the resistance programs that best modify blood lipid profiles incorporate larger muscle mass and multisegment exercises with a high total-volume (reps x sets x load) prescription. Additional research needs to be conducted that controls for body composition changes, day-to-day variations in lipoproteins, dietary factors and possible other training adaptations, to provide a more credible summary of the effect of resistance training on blood lipids and lipoproteins.

Barr SI, et.al. (1991) assessed whether a previously described dose-response relationship between the amount of exercise and the magnitude of change in blood lipid and lipoprotein levels is observed with large volumes of exercise in young, healthy individuals. Blood lipid and lipoprotein levels were monitored during a 25-wk season of training and competition in experienced male collegiate swimmers, who were divided into two groups matched for swimming skill. After an initial 4-wk conditioning period for both groups, one group (N = 11) underwent a 6-wk period during which their training volume was increased from 22,000 m.wk-1 to 44,000 m.wk-1. The other group (N = 13) maintained their swimming distance at 22,000 m.wk-1 during this period. During the remaining 15 wk of the season, both groups swam approximately 22,000 m.wk-1. Swimmers' body weights did not change over the season, but body fat decreased significantly (P less than 0.01). No changes in HDL cholesterol were observed during the season in either the increased training or the regular training groups. Total and LDL cholesterol levels were lower at 20 wk than at the start of the study, but final levels did not differ from initial levels.

Thus, the volume of swimming exercise may not be related to the degree of change in blood lipid and lipoprotein levels in healthy subjects with high activity levels.

Takeshima et. al. (2004) determine the physiological effects of a programmed accommodating circuit exercise (PACE) program consisting of aerobic exercise and hydraulic-resistance exercise (HRE) on fitness in older adults. Thirty-five volunteers were randomly divided into two groups [PACE group (PG) 8 men and 10 women, 68.3 (4.9) years, and non-exercise control group (CG) 7 men and 10 women, 68.0 (3.4) years). The PG participated in a 12-week, 3 days per week supervised program consisting of 10 min warm-up and 30 min of PACE (moderate intensity HRE and aerobic movements at 70% of peak heart rate) followed by 10 min cool-down exercise. PACE increased (P<0.05) oxygen uptake (V(.)O(2)) at lactate threshold [PG, pre 0.79 (0.20) l min(-1), post 1.02 (0.22) l min(-1), 29%; CG, pre 0.87 (0.14) l min(-1), post 0.85 (0.15) l min(-1), -2%] and at peak V(.)O(2) [PG, pre 1.36 (0.24) l min(-1), post 1.56 (0.28) l min(-1), 15%; CG, pre 1.32 (0.29) l min(-1), post 1.37 (0.37) l min(-1), 4%] in PG measured using an incremental cycle ergometer. Muscular strength evaluated by a HRE machine increased at low to high resistance dial settings for knee extension (9-52%), knee flexion (14-76%), back extension (18-92%) and flexion (50-70%), chest pull (6-28%) and press (3-17%), shoulder press (18-31%) and pull (26-85%), and leg press (21%). Body fat (sum of three skinfolds) decreased (16%), and high-density lipoprotein cholesterol (HDLC) increased (10.9 mg dl(-1)) for PG. There were no changes in any variables for

CG. These results indicate that PACE training incorporating aerobic exercise and HRE elicits significant improvements in cardiorespiratory fitness, muscular strength, body composition, and HDLC for older adults. Therefore, PACE training is an effective well-rounded exercise program that can be utilized as a means to improve health-related components of fitness in older adults.

Linossier MT, et.al. (1997) studied the effect of sprint training and detraining on supramaximal performances was studied in relation to muscle enzyme adaptations in eight students trained four times a week for 9 weeks on a cycle ergometer. The subjects were tested for peak oxygen uptake (VO2peak), maximal aerobic power (MAP) and maximal short-term power output (Wmax) before and after training and after 7 weeks of detraining. During these periods, biopsies were taken from vastus lateralis muscle for the determination of creatine kinase (CK), adenylate kinase (AK), glycogen phosphorylase (PHOS), hexokinase (HK), phosphofructokinase (PFK), lactate dehydrogenase (LDH) and its isozymes, 3-hydroxy-acyl-CoA dehydrogenase (HAD) and citrate synthase (CS) activities. Training induced large improvements in Wmax (28%) with slight increases (3%) in VO2peak ($P < 0.10$). This was associated with a greater glycolytic potential as shown by higher activities for PHOS (9%), PFK (17%) and LDH (31%) after training, without changes in CK and oxidative markers (CS and HAD). Detraining induced significant decreases in VO2peak (4%), MAP (5%) and oxidative markers (10-16%), while Wmax and the anaerobic potential were maintained at a high level. This suggests a high level in supramaximal power output as a result of a muscle glycogenolytic and glycolytic adaptation. A long interruption in training has negligible effects on short-sprint ability and muscle anaerobic potential. On the other hand, a persistent training stimulus is required to maintain high aerobic capacity and muscle oxidative potential. This may contribute to a rapid return to competitive fitness for sprinters and power athletes.

Yonezawa K. (1990) studied that anaerobic threshold (AT) has been advocated as an objective method of evaluating exercise capacity in patients with chronic congestive heart failure. The factors that determine AT, however, remain still unclear. To assess the influence of oxygen transport capacity on AT, patients with iron deficiency anemia were studied before and after treatment with iron. Twenty-nine female subjects were studied. They were divided into the following 3 groups: 1) iron deficiency anemia (group IDA: Hgb less than 11 g/dl and ferritin less than 10 ng/ml) consisting of 4 athletes and 6 non-athletes, 2) latent iron deficiency (group Lat-ID: Hgb greater than or equal to 11 g/dl and ferritin less than 10 ng/ml) consisting of 4 athletes, and normal (group Nor: Hgb greater than or equal to 11 g/dl and ferritin greater than or equal to 10 ng/ml) consisting of 15 athletes and 6 non-athletes. By bicycle ergometer using ramp protocol, peak oxygen uptake (peak VO2) and AT were measured in each group. Following the 1st exercise testing, groups IDA and Lat-ID were treated by oral iron for 1-1.5 months. The 2nd exercise testing was then performed. Furthermore, to investigate whether muscle cell energy metabolism itself is altered by iron deficiency, P magnetic resonance spectroscopy (MRS) was performed in 2 relatively severe anemic patients during forearm exercise while assessing the changes in phosphocreatine and inorganic phosphate. Peak VO2 and AT in non-athletes were significantly lower in IDA group than Nor group (peak VO2 (ml/min/kg): 23.7 +/- 5.1 vs 33.3 +/- 3.8, p less than 0.01, AT (ml/min/kg): 15.9 +/- 3.3 vs 21.3 +/- 1.3, p less than 0.01). After iron administration, Hgb was increased significantly in IDA group (from 9.0 +/- 1.8 to 12.1 +/- 0.8 g/dl, p less than 0.01) accompanied by an improvement in peak VO2 and AT (peak VO2 (ml/min/kg): from 34.2 +/- 12.4 to 40.0 + 13.0, p less than 0.001, AT (ml/min/kg): from 20.9 +/- 6.3 to 25.0 +/- 8.0, p less than 0.001). Lat-ID and Nor groups showed no changes. MRS indices of cell energy metabolism of the 2 severely anemic patients did not differ from those of normal controls, and no changes were observed after iron treatment. It is concluded from these results in iron deficiency anemia that oxygen transport is a determinant of anaerobic threshold.

Schoene RB, et.al. (1983) studied the effect of 2 weeks of iron therapy on exercise performance and exercise-induced lactate production in trained women athletes: six control subjects with normal parameters of iron status and nine with mild iron-deficiency anemia defined by low Fe/TIBC, ferritin, and minimally decreased Hgb values. Iron therapy improved the abnormal measures of iron status and low Hgb in the second group to normal. Exercise performance in a progressive work-exercise protocol on a bicycle ergometer to exhaustion was unchanged after iron therapy in both groups; however, blood lactate levels at maximum exercise in the iron-deficient group decreased significantly from 10.3 +/- 0.6 mmol/L before therapy to 8.42 +/- 0.7 after therapy (p less than

0.03). The control subjects did not significantly alter lactate levels after maximal exercise on iron compared to placebo: 8.3 +/- 0.8 mmol/L vs. 8.5 +/- 0.7. Although there was not a significant difference in maximum exercise performance after iron therapy, these data support animal experiments implying that iron may play a role in oxidative metabolism and that minimal decreases in Hgb may impair arterial oxygen content enough to affect aerobic metabolism. In addition, these findings may have important implications for competitive women athletes in whom mild iron deficiency may go unnoticed.

Boyadjiev and Taralov, (2000) recorded the basic red blood cell variables in highly trained pubescent athletes of both the sexes from different sports and compared with those of the untrained group. Highly trained athletes numbering 876 (559 boys and 317 girls) with mean age, weight and duration of training of 14.01 years, 56.24 kg and 3.52 years, respectively. The control group consisted of 357 untrained subjects (171 boys and 186 girls) with mean age and weight of 14.58 years and 57.75 kgs., respectively. The athletes were divided into seven subgroups as athletics (105), swimming (107), rowing (230), wrestling (225), weight lifting (47), various team sports (92) and other sports (67). Venous blood samples were drawn from the cubital vein and the red blood cell count, packed cell volume, hemoglobin concentration and mean corpuscular volume were measured and statistically analysed by factorial analysis of variance to evaluate the statistical significance of the differences. The highly trained group had lower red blood cell count, packed cell volume and hemoglobin concentration than the control untrained group.

Ciloglu F, (2005) studied that physical activity influences energy metabolism in human subjects by increasing activity-induced energy expenditure and resting metabolic rate for several hours after exercise. Effects of exercise on circulating thyroid hormone values remain controversial. We have investigated the effect of acute aerobic exercise on thyroid hormone values. The effect of different intensity levels of acute aerobic exercise on thyroid hormones was investigated in 60 male well-trained athletes by performing bicycle ergometer at 45% (low intensity), 70% (moderate intensity), and 90% (high intensity). These intensities were selected according to their maximum heart rate (MHR). At each intensity level, heart rate, blood lactic acid, serum total thyroxine (T4), free thyroxine (fT4), total triiodothyronine (T3), free triiodothyronine (fT3) and thyroid stimulating hormone (TSH) values were measured. The results of this study show that exercise performed at the anaerobic threshold (70% of maximum heart rate, lactate level 4.59 +/- 1.75 mmol/l) caused the most prominent changes in the amount of any hormone values. While the rate of T4, fT4, and TSH continued to rise at 90% of maximum heart rate, the rate of T3 and fT3 started to fall. Maximal aerobic exercise greatly affects the level of circulating thyroid hormones.

2.2 STUDIES ON EFFECT OF PLYOMETRIC TRAINING

Shahram Alam et.al. (2012) fond out the effect of plyometric circuit exercises on the physical preparation indices of elite handball player in the city of Behbahan. In this research, 20 elite male athletes (year 17-19) participated. The participants were chosen non-randomly from the high school male students and they participated in four tests (vertical jump -shuttle briskness-medicine ball throw - 30 meters speed run). After making them homogeneous, the participants were divided randomly into two groups, i.e. experimental (plyometric circuit exercises) and control group (only handball exercises). They participated in the exercises for 6 weeks and each week 3 sessions and each session 90 minutes. After completion of the course, both groups participated in a post-test. The participants' records were registered in 4 pre- and post-tests and compared. The results of the study revealed that 6 weeks plyometric circuit exercises have meaningful effect on the participants' records in four tests (vertical jump-shuttle briskness- medicine ball throw- 30 meters speed run) and have caused improvements in the results of these four tests. Therefore, it seems that plyometric circuit exercises have been effective on the physical preparation indices of handball players and can improve the athletes' performance of this field.

Clutch et al. (2001) examined the effect of depth jumps and weight training on leg strength and vertical jump in two studies. The effect of depth jumping (plyometrics) and traditional weight training on performance of vertical jump and other measures of length are reviewed below.

Three jumping activities were compared (a) maximum vertical jump (b) 0.3 m depth jumps and (c) 0.75 and 1.10 m depth jumps. These activities were preceded by three weeks of weight training. Weight training with jumping activities was conducted for twice in a week for four weeks. All groups demonstrated similar improvements on 1 RM squat strength, isometric knee-extension strength, and vertical jump. The lack of significant differences could have been due to the small group sizes. It restricted the statistical power for the analysis. A weight along group (N=14) compared to weight plus depth jumping group (N=14). Training was performed twice per week for 16 weeks. The weight training group did not improve vertical jump although strength parameters improved. The weight plus jumping group did improve in the vertical jump. It was found that weight plus jumping produced no added beneficial performance improvement than the jumping alone group. The weight training programme did not provide added benefit.

Wilson et al. (1994) conducted a study on the optimal training load for the development of dynamic athletic performance. Traditional weight training group, plyometric training group, dynamic weight training groups and a control og recreationally weight trained individuals were compared on 30 m sprint, vertical jump without counter movement, maximal cycle test, isotonic leg extension and maximal isometric tests.The results showed that the dynamic weight training was the only training group that produced significant changes in all measures than the traditional weight training group and plyometric training group.

Fletcher and Hertwell (2002) examined the effect of an 8 week combined weights and plyometrics training program on golf drive performance. Eleven golfers were randomly assigned to control and experimental group. The control group continued their current training programmes. The experimental group performed combined weight and plyometric training twice in a week.

The treatment group showed significant changes in head speed and driving distance.

Hortobagyi, et al., (1991) examined the effects of simultaneous training for strength and endurance on upper and lower body strength and running performance. High Resistance (HR), Low Resistance (LR) and Control groups of college men were used as subjects without the difference in body compositions in fitness. It was concluded that gains in strength were compromised by simultaneous endurance training. High resistance or low resistance training did not affect the gains in strength and endurance. It would appear to be unproductive to mix strength and endurance training because an athlete would gain maximum benefits in the mixed training.

Schantz and Kallman (1989) conducted a study on the relationship between strength training programme effects and aerobic endurance adaptations. Strength training programmes are considered to be anaerobic in nature. Muscle biopsies were taken from three groups (a) strength trained athletes (b) endurance trained swimmers and (c) a non trained control group. It was concluded that strength training did not effect the enzymes associated with aerobic metabolism.

Housh, et al., (1995) examined the effect of eccentric dynamic constant external resistance training on concentric isokinetic torque velocity curve. This study showed that the nature of strength training stimulus (dynamic constant external resistance) only improved strength performances in its training exercises and testing activities. It supported the notion of specificity of testing and training. Concentric isokinetic testing was not sensitive to changes brought about by eccentric training. It implied that strength training was more likely to benefit the activities than other training.

Balabins (2001) conducted a research on the effects of concurrent endurance and strength training. The study was conducted for 26 male basketball players. They were divided into four groups of strength and endurance groups and a control group. All groups except control group was trained four times a week for seven weeks. The strength and endurance groups perfomed both the endurance and strength programme with a seven hours recovery. Improvements were seen for all the groups according to their training in vertical jump, anaerobic power (Wingate Test) and aerobic capacity (1 mile walk). This was higher for the strength and endurance training group than the other groups. On all measures the strength training group alone increased anaerobic power but with decreased aerobic capacity. The endurance training group increased aerobic capacity with decreased anaerobic power. The results of the study showed that the concurrent strength and endurance training improved anaerobic power better than strength training alone and it improved VO_2 max better than endurance training alone.

Sowyer et al.,(2004) analysed a study on relationship between football playing ability and selected performance measures. Forty football players were tested on selected performances – vertical jump, 20 yard dash, pro shuttle run, bench press, squat, power clean and snatch. The players were grouped together based upon position. According to the statistical analysis the vertical jump was the only variable that was significantly correlated with football playing ability in all groups. The results indicated that the temporal aspects of vertical jump were organised in the central nervous system in a similar way to that of football playing ability.

Green and Dowson (2002) studied the measurement of anaerobic capacity in human body. The study focuses on laboratory measures which attempts to quantify anaerobic capacities. Maximal blood lactate measure was used in both research and athletic settings to decrease anaerobic capacity. Its uses was supported by (a) the high correlations observed between maximal blood lactate and short duration exercise performance presumably dependant upon anaerobic capacity and (b) the higher maximal blood lactates values observed in sprint and power athletes (who would demonstrate higher anaerobic capacities) compared with endurance athletes or untrained people. The latter findings may be partially related to the confounding influence of blood volume which such high variability response to short and long term exercise demands. Maximal blood lactate was known to be influenced by the intensity and duration of the preceding exercise bout; therefore it was plausible that these factors may also influence the degree for which maximal blood lactate accurately reflects an aerobic capacity.

Williams (2003) conducted a study on children’s and adolescents anaerobic performance during cycle ergometry. The anaerobic test, friction braked wingate, other tests such as the fork velocity and isokinetic cycle ergometers were becoming more common. There was unequivocal agreement that children's and adolescents anaerobic power scores were lower than those of adults. Qualitative muscular differences were often cited for this disparity rather than differences in the quantity of muscle, but conclusive research was lacking in this area.

Bacharach and Davillard (2004) examined a study of intermediate and a long term anaerobic performance of elite Alpine skiers. Many researchers identified that Alpine skiers need muscular strength and complex motor skill abilities. After verifying a variety of tests short test of anaerobic capacity came into existence. Seventeen Nationally ranked male and female Alpine ski racers from USA were used. The power was measured in them by keeping 30.5 and 90.5 Wingate Cycle Ergometer tests. Through this study they found that the capacity of anaerobic power can be altered.

Hoffman et al., (2004) have conducted a study on the comparison between the Wingate Anaerobic power test both vertical jump motive drill tests in basketball players. Israel National Youth basketball team players participated as subjects. The field tests of 15 second anaerobic jump test and a sprint test was taken and laboratory test of Wingale Anaerobic power test was taken three times for the same group. Laboratory test of Wingate Anaerobic power test was taken to determine peak power, mean power and fatigue index. No significant correlations were observed between peak power and sprint test, but significant positive correlations were noted between vertical jump and the peak power and mean power. The results suggested that the line skill and jump tests might be acceptable field measures of anaerobic power specific to basketball players.

Astrand and Radahl (1986) defined lactate system as anaerobic glycolysis which has essentially the incomplete breakdown of glycogen in the absence of oxygen. It occurred during the period of maximal exercise testing approximately 90 seconds in duration. The result showed that the corresponding increase in muscle activity which caused muscle fatigue due to the accumulation of H+ one possible explanation for the fatigue was due to the inhibition of phosphor fructoknare (PFK) which was essential for the production of ATP.

Bernard (1998) examined the differences between the results of three different anaerobic power test: a 50 m dash, vertical jump and differences between the results of three different trials of day. A group of 23 men undertook each of the three tests on three separate days at 0900, 1400 and 1800 hours. Results showed that anaerobic power and max running speed were significantly lower in the morning compared with the afternoon with 56.07% greater power achieved in the afternoon. There were no differences between either afternoon test times. For fitness testing procedures, trainers need to be consistent with time at day when the tests were performed. The best time of day for anaerobic training was early evening.

Powerman (2003) elaborated his idea in the article of “Super Training” in which he described about speed. The researcher used a method of training to improve speed by the maximal and dynamic effect methods, heavy load training, light load training, shock method (plyometrics) and researcher prescribed the entire training period in a macrocycle. Connective tissues strengthen and adapt to stresses imposed because of the training. The researcher concludes that any property applied programme would generally implement and increase the loading involved for any means of training, so as to minimize the risk of injury – speed and strength.

Reynold (2004) emphasized that workouts can boost fitness, speed, endurance and correct weaknesses. The researcher introduced “run-play” workouts which was a variation of conventional fartlek or “speed-play”. The training method involved a mixture of running, bounding and sprinting exercises that were combined with mobility and agility drives. It can be altered according to the needs of athletes. The results concluded that organised training emphasized the specific characteristics for a sprinter. It developed greater leg power, acceleration and maximal speed for a middle distance competitor. It improved basic speed and speed endurance and for a distance runner better speed endurance and aerobic endurance were developed.

Lockie, et al. (2003) tested and examined the effects of resisted sled towing on spring kinematics in field sport athletes. Twenty men completed a series of sprints without resistance and with loads equating to 12.6 and 32.21 of their body mass. Stride length was significantly reduced by approximately 10 and 24 percent for each load. Stride frequency also decreased but not to the extent of stride length. Other notable changes in kinematics were increased ground contact time, trunk lean and hip flexion and increased shoulder range of motion with the greater resistance. Generally, the greater the load, the greater the disruption from normal acceleration mechanics. The conclusions arrived were A resisted sled towing protocol may be very effective in order to overload on athletics sprint technique and develop the specific recruitment of fast twitch muscle fibers'

Will and Freeman (1984) after giving an in depth study on different study on different types of training philosophies and techniques in track and field, and suggested that proper use of these techniques can add to the speed, quickness and jumping and throwing ability of athletes based on their successful implementation of the plyometric techniques for several years to their track at Grindel College.

Schall, et al. (2003) conducted a study of effects of magnetic therapy on selected physical performances. Fourteen soccer players were put through a battery of four tests to evaluate athletic performance. It includes vertical jump, 40 yard sprint, bench squad and soccer specific fitness test. During their training sessions of seven weeks magnetic insules were applied. The results showed that there was no significant improvement between the control and treatments group in pre and post testing scores indicating no increase in performance. Specifically 40 yards sprint scores and vertical jump scores declined. There was only a minor increase in bench squat and soccer fitness tests. Thus the results do not support using magnets for increasing performance in the athletic arena, Moore et.al.

Markovic et al. (2007) conducted a research study the precise effect of plyometric training (PT) on vertical jump height in healthy individuals. Metaanalyses of randomised and non-randomised controlled trials that evaluated the effect of PT on four typical vertical jump height tests were carried out: squat jump (SJ); countermovement jump (CMJ); countermovement jump with the arm swing (CMJA); and drop jump (DJ). Studies were identified by computerised and manual searches of the literature. Data on changes in jump height for the plyometric and control groups were extracted and statistically pooled in a meta-analysis, separately for each type of jump. 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 of the effect of PT on vertical jump height was 4.7% (95% CI 1.8 to 7.6%), 8.7% (95% CI 7.0 to 10.4%), 7.5% (95% CI 4.2 to 10.8%) and 4.7% (95% CI 0.8 to 8.6%) for the SJ, CMJ, CMJA and DJ, respectively. When expressed in standardised units (ie, effect sizes), the effect of PT on vertical jump height was 0.44 (95% CI 0.15 to 0.72), 0.88 (95% CI 0.64 to 1.11), 0.74 (95% CI 0.47 to 1.02) and 0.62 (95% CI 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). These results justify the application of PT for the purpose of development of vertical jump performance in healthy individuals.

Impellizzeri et al. (2008) examined to compare the effects of plyometric training on sand versus a grass surface on muscle soreness, vertical jump height and sprinting ability.Parallel two-group, randomised, longitudinal (pretest-post-test) study. After random allocation, 18 soccer players completed

4 weeks of plyometric training on grass (grass group) and 19 players on sand (sand group). Before and after plyometric training, 10 m and 20 m sprint time, squat jump (SJ), countermovement jump (CMJ), and eccentric utilization ratio (CMJ/SJ) were determined. Muscle soreness was measured using a Likert scale. No training surface x time interactions were found for sprint time ($p>0.87$), whereas a trend was found for SJ ($p = 0.08$), with both groups showing similar improvements ($p<0.001$). On the other hand, the grass group improved their CMJ ($p = 0.033$) and CMJ/SJ ($p = 0.005$) significantly ($p<0.001$) more than players in the sand group. In contrast, players in the sand group experienced less muscle soreness than those in the grass group ($p<0.001$).Plyometric training on sand improved both jumping and sprinting ability and induced less muscle soreness. A grass surface seems to be superior in enhancing CMJ performance while the sand surface showed a greater improvement in SJ. Therefore, plyometric training on different surfaces may be associated with different training-induced effects on some neuromuscular factors related to the efficiency of the stretch-shortening cycle.

Ratamess et al. (2007) examined the combined effects of resistance and sprint/plyometric training with or without Meridian Elyteathleti c shoe on muscular performance in women. Fourteen resistance trained women were randomly assigned to one of 2 training groups: (a) an athletic shoe (N = 6) (AS) group or (b) the Meridian Elite (N = 8) (MS) group. Training was performed for 10 weeks and consisted of resistance training for 2 days per week and 2 days per week of sprint/ plyometric training. Linear periodized resistance training consisted of 5 exercises per workout (4 lower body, 1 upper body) for 3 sets of 3-12 repetition maximum (RM). Sprint/plyometric training consisted of 5-7 exercises per workout (4-5 plyometric exercises, 40-yd and 60-yd sprints) for 3-6 sets with gradually increasing volume (8 weeks) followed by a 2-week taper phase. Assessments for 1RM squat and bench press, vertical jump, broad jump, sprint speed, and body composition were performed before and following the 10-week training period. Significant increases were observed in both AS and MS groups in 1RM squat (12.0 vs. 14.6 kg), bench press (6.8 vs. 7.4 kg), vertical jump height (3.3 vs. 2.3 cm), and broad jump (17.8 vs. 15.2 cm). Similar decreases in peak 20-, 40-, and 60-m sprint times were observed in both groups (20 m: 0.14 vs. 0.11 seconds; 40 m: 0.29 vs. 0.34 seconds; 60 m: 0.45 vs. 0.46 seconds in AS and MS groups, respectively). However, when sprint endurance (the difference between the fastest and slowest sprint trials) was analyzed, there was a significantly greater improvement at 60 m in the MS group. These results indicated that similar improvements in peak sprint speed and jumping ability were observed following 10 weeks of training with either shoe. However, high-intensity sprint endurance at 60 m increased to a greater extent during training with the Meridian Elyte athleticshoe.

De Villarreal et al. (2008) conducted a research study the effect of 3 different plyometric training frequencies (e.g., 1 day per week, 2 days per week, 4 days per week) associated with 3 different plyometric training volumes on maximal strength, vertical jump performance, and sprinting ability. Forty-two students were randomly assigned to 1 of 4 groups: control (n = 10, 7 sessions of drop jump (DJ) training, 1 day per week, 420 DJs), 14 sessions of DJ training(n = 12, 2 days per week, 840 DJs), and 28 sessions of DJ training (n = 9, 4 days per week, 1680 DJs). The training protocols included DJ from 3different heights 20, 40, and 60 cm. Maximal strength (1 repetition maximum [1RM] and maximal isometric strength), vertical height in countermovement jumps and DJs, and 20-m sprint time tests were carried out before and after 7 weeks of plyometric training. No significant differences were observed among the groups in pre-training in any of the variables tested. No significant changes were observed in the control group in any of the variables tested at any point. Short-term plyometric training using moderate training frequency and volume of jumps (2 days per week, 840 jumps) produces similar enhancements in jumping performance, but greater training efficiency (approximately 12% and 0.014% per jump) compared with high jumping (4 days per week, 1680 jumps) training frequency (approximately 18% and 0.011% per jump). In addition, similar enhancements in 20-m-sprint time, jumping contact times and maximal strength were observed in both a moderate and low number of training sessions per week compared with high training frequencies, despite the fact that the average number of jumps accomplished in 7S (420 jumps) and 14S (840 jumps) was 25 and 50% of that performed in 28S (1680 jumps). These observations may have considerable practical relevance for the optimal design of plyometric training programs for athletes, given that a moderate volume is more efficient than a higher plyometric training volume.

Thomas et al. (2009) investigated the effects of two plyometric training techniques on power and agility in youth soccer players. Twelve males from a semiprofessional football club's academy (age = 17.3 +/- 0.4 years, stature = 177.9 +/- 5.1 cm, mass = 68.7 +/- 5.6 kg) were randomly assigned to 6 weeks of depth jump (DJ) or countermovement jump (CMJ) training twice weekly. Participants in the DJ group performed drop jumps with instructions to minimize ground-contact time while maximizing height. Participants in the CMJ group performed jumps from a standing start position with instructions to gain maximum jump height. Post training, 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 concludes that both DJ and CMJ Plyometric are worthwhile training activities for improving power and agility in youth soccer players.

Vescovi et al. (2008) examined the effects of a plyometric program on peak vertical ground reaction force as well as kinetic jumping characteristics in recreationally athletic college women.Six week prospective exercise intervention. Division I university campus. Twenty college females who competed recreationally in basketball were randomly assigned to a training (n=10) or control (n=10) group. The absolute change values for vertical ground reaction force, countermovement jump height, peak and average jump power, and peak jump velocity. Comparisons were made using Mann-Whitney U tests. Vertical ground reaction force decreased in the intervention group (-222.8+/-610.9N), but was not statistically different (p=0.122) compared to the change observed in the control group (54.6+/-257.6N). There was no difference in the absolute change values between groups for countermovement jump height (1.0+/-2.8cm vs. -0.2+/-1.5cm, p=0.696) or any of the associated kinetic variables following the 6-week intervention. Although not statistically significant, the mean absolute reduction in vertical ground reaction force in the training group is clinically meaningful. Eight of the 10 women in the training group reduced vertical ground reaction force by 17-18%; however, improvements in jumping performance were not observed. This indicates that programs aimed at enhancing performance must be designed differently from those aimed at reducing landing forces in recreationally athletic women.

Potach et al.(2009) conducted a research study plyometric training program can affect the latency time of the quadriceps femoris and gastrocnemius short-latency responses (SLRs) of the stretch reflex. Sixteen healthy subjects (12 female and 4 male) were randomly assigned to either a control or a plyometric training group. Maximum vertical jump height (VJ) and SLRs of both quadriceps femoris and gastrocnemius were measured before and after a four week plyometric training program.Plyometric training significantly increased VJ (mean+/-SEM) by 2.38+/-0.45 cm (P<0.05) and non-significantly decreased the latency time of the quadriceps femoris SLR (mean+/-SEM) 0.363+/-0.404 ms (P>0.05) and gastrocnemius SLR (mean+/-

SEM) 0.392+/-0.257 ms ($P>0.05$). VJ results support the effectiveness of plyometric training for increasing VJ height. The non-significant changes in the latency time of the quadriceps femoris and gastrocnemius SLRs seen in the training group suggest that performance improvements following a four-week plyometric training program are not mediated by changes in the latency time of the short-latency stretch reflex.

De Villarreal et al. (2009) investigated Plyometric training improves vertical jump height (VJH). However, the effectiveness of plyometric training depends on various factors. A meta-analysis of 56 studies with a total of 225 effect sizes (ESs) was carried out to analyze the role of various factors on the effects of plyometrics on VJH performance. The inclusion criteria for the analysis were a) studies using plyometric programs for lower-limb muscles, b) studies employing true experimental designs and valid and reliable measurements, and c) studies including enough data to calculate ESs. Subjects with more experience in sport obtained greater enhancements in VJH performance ($p < 0.01$). Subjects in either good or bad physical condition benefit equally from plyometric work ($p < 0.05$), although men tend to obtain better power results than women after plyometric training ($p < 0.05$). With relation to the variables of performance, training volumes of more than 10 weeks and more than 20 sessions, using high-intensity programs (with more than 50 jumps per session), were the strategies that seemed to maximize the probability of obtaining significantly greater improvements in performance ($p < 0.05$). To optimize jumping enhancement, the combination of different types of plyometrics (squat jump + countermovement jump + drop jump) is recommended rather than using only 1 form ($p < 0.05$). However, no extra benefits were found to be gained from doing plyometrics with added weight. The responses identified in this analysis are essential and should be considered by strength and conditioning professionals with regard to the most appropriate dose-response trends for optimizing plyometric-induced gains.

Meylan et al. (2009) investigated the influence of short-term plyometric training within regular soccer practice on explosive actions of early pubertal soccer players during the in-season. Fourteen children (13.3 +/- 0.6 years) were selected as the training group (TG) and 11 children (13.1 +/- 0.6 years) were defined as the control group (CG). All children were playing in the same league and trained twice per week for 90 minutes with the same soccer drills. The TG followed an 8-week plyometric program (i.e., jumping, hurdling, bouncing, skipping, and footwork) implemented as a substitute for some soccer drills to obtain the same session duration as CG. At baseline and after training, explosive actions were assessed with the following 6 tests: 10-meter sprint, agility test, 3 vertical jump tests (squat jump [SJ], countermovement jump [CMJ], contact test [CT] and multiple 5 bounds test [MB5]). Plyometric training was associated with significant decreases in 10-m sprint time (-2.1%) and agility test time (-9.6%) and significant increases in jump height for the CMJ (+7.9%) and CT (+10.9%). No significant changes in explosive actions after the 8-week period were recorded for the CG. The current study demonstrated that a plyometric program within regular soccer practice improved explosive actions of young players compared to conventional soccer training only. Therefore, the short-term plyometric program had a beneficial impact on explosive actions, such as sprinting, change of direction, and jumping, which are important determinants of match-winning actions in soccer performance.

Rubley et al. (2011) conducted a research study the effects of low-frequency, low-impact plyometric training on vertical jump (VJ) and kicking distance in female adolescent soccer players. Sixteen adolescent soccer players were studied (age 13.4 ± 0.5 years) across 14 weeks. The control group (general soccer training only) had 6 subjects, and the plyometric training (general soccer training plus plyometric exercise) group had 10 subjects. All subjects were tested for VJ and kicking distance on 3 occasions: pre-test, 7 weeks, and 14 weeks. Data were analyzed using a 2 (Training) × 3 (Test) analysis of variance (ANOVA) with repeated measures on the factor test. No significant difference in kicking distance was found between groups at pre-test ($p = 0.688$) or 7 weeks ($p = 0.117$). The plyometric group had significantly greater kicking distance after 14 weeks ($p < 0.001$). No significant difference in VJ height was found between groups at pre-test ($p = 0.837$) or 7 weeks ($p = 0.108$). The plyometric group had a significantly higher VJ after 14 weeks ($p = 0.014$). These results provide strength coaches with a safe and effective alternative to high-intensity plyometric training. Based on these findings, to increase lower-body power resulting in increased VJ and kicking distance, strength coaches should implement once-weekly, low-impact plyometric training programs with their adolescent athletes.

Herrero et al. (2010) investigated the effects of combined strength and plyometric training with or without super imposed Delectromyo stimulation (EMS) on muscle strength and anaerobic power. Twenty-nine subjects were randomly assigned to weight + plyometrics + EMS (EP), weight + plyometrics (VP), and control group (CG). Weight + plyometrics+EMS and VP performed 2 plyometric sessions and 2 weight training sessions per week throughout 4 weeks on a knee extension machine. Weight + plyometrics + EMS received EMS throughout the concentric phase of each action (120 Hz, 400 microseconds). Before, after training, and 2 weeks after the end of the training (detraining), maximal voluntary contraction, squat jump, countermovement jump, countermovement jump with free arms, and 20-minute sprint time were analyzed. After the training period, EP and VP increased their muscle strength (28.6 and 22.3%, respectively; $p<0.001$). After the detraining period, this gain remained above baseline values (28.1 and 18.0%, respectively; $p<0.001$ and $p<0.01$). After training and detraining, muscle strength was higher in EP than in VP ($p<0.05$). Vertical jump height was not modified for whichever group or test, except for the countermovement jump height with free arms, where a decrease for EP was observed after training (-6.3%; $p<0.001$) and detraining (-5.5%; $p<0.001$). Sprint performance improved in all groups in the detraining test (-0.8%; $p<0.05$). If a low number of training sessions are carried out, superimposed EMS leads to a higher strength gain than voluntary training alone. However, if anaerobic power is an important aim of the training, EMS should be applied isometrically instead of superimposed EMS and combined with plyometrics.

Berryman et al. (2010) conducted a research study the effects of 2 strength training methods on the energy cost of running (Cr). Thirty-five moderately to well-trained male endurance runners were randomly assigned to either a control group (C) or 2 intervention groups. All groups performed the same endurance-training program during an 8-week period. Intervention groups added a weekly strength training session designed to improve neuromuscular qualities. Sessions were matched for volume and intensity using either plyometric training (PT) or purely concentric contractions with added weight (dynamic weight training [DWT]). They found an interaction between time and group ($p < 0.05$) and an effect of time ($p < 0.01$) for Cr. Plyometric training induced a larger decrease of Cr (218 +/- 16 to 203 +/- 13 ml.kg.km) than DWT (207 +/- 15 to 199 +/- 12 ml.kg.km), whereas it remained unchanged in C. Pre-post changes in Cr were correlated with initial Cr ($r = -0.57$, $p < 0.05$). Peak vertical jump height (VJHpeak) increased significantly ($p < 0.01$) for both experimental groups (DWT = 33.4 +/- 6.2 to 34.9 +/- 6.1 cm, PT = 33.3 +/- 4.0 to 35.3 +/- 3.6 cm) but not for C. All groups showed improvements ($p < 0.05$) in Perf3000 (C = 711 +/- 107 to 690 +/- 109 seconds, DWT = 755 +/- 87 to 724 +/- 77 seconds, PT = 748 +/- 81 to 712 +/- 76 seconds). Plyometric training were more effective than DWT in improving Cr in moderately to well-trained male endurance runners showing that athletes and coaches should include explosive strength training in their practices with a particular attention on plyometric exercises. Future research is needed to establish the origin of this adaptation.

Ball et al. (2010) investigated to bilaterally analyze the ground reactions forces and temporal components of drop jumping from 3 heights. Ten recreationally active male subjects completed 3 bounce-drop jumps from 3 starting heights (0.2, 0.4, and 0.6 m). Two linked force platforms were used to record left- and right-leg peak vertical force, time to peak force, average force, ground contact time, impulse and time differential. Between-height and between-leg comparisons for each variable were made using a multivariate analysis of variance with post hoc Wilcoxon tests ($p < 0.05$). Results indicated that force and time variables increased as drop jump height increased ($p < 0.0001$). Post hoc analyses showed that at 0.2- and 0.4-m bilateral differences were present in the time to peak force, average force, and impulse. No bilateral differences for any variables were shown at 0.6-m starting height. The contact time for all jumps was <0.26 seconds. At 0.2 m, only 63% of the subjects had a starting time differential of <0.01 seconds, rising to 96.3% at 0.6 m. The results indicated that 0.6 m is the suggested drop jump height to ensure that no bilateral differences in vertical forces and temporal components occur; however, shorter contact times were found at the lower heights.

Ebben et al. (2010) conducted a research study to introduce a modification of the RSI (RSImod) that can be used to evaluate the explosive power of any vertical plyometric exercise. This study will also assess the reliability of the RSImod, evaluate the RSImod of a variety of plyometric exercises, and examine gender differences. Twenty-six men and 23 women served as subjects. Subjects performed 3 repetitions for each of 5 plyometric exercises including the countermovement jump (CMJ), tuck jump, single-leg jump, squat jump, and dumbbell CMJ. Data were analyzed using a 2-way analysis of variance to evaluate differences in RSImod between the plyometric exercise and the interaction between plyometric exercise RSImod and gender. The analysis of RSImod revealed significant main effects for plyometric exercise type (p <or= 0.001) but not for the interaction between plyometric exercise type and gender ($p > 0.05$). Results of pairwise comparisons indicate that the RSImod is statistically different between all plyometric exercises studied. Intraclass correlation coefficients indicate that RSImod is highly reliable for all of the exercises studied. The RSImod offers a highly reliable method of assessing the explosiveness developed during a variety of plyometric exercises.

King et al. (2010) conducted a research study to evaluate whether frontal plane (FP) plyometrics, which are defined as plyometrics dominated with a lateral component, would produce similar increases in vertical jump height (VJH) compared to sagittal plane (SP) Plyometrics. Thirty-two junior varsity and varsity high-school basketball players participated in 6 weeks of plyometric training. Players participated in either FP or SP plyometrics for the entire study. Vertical jump height was measured on 3 occasions: preintervention (baseline), at week 3 of preparatory training, and at week 6 of training. Descriptive statistics were calculated for VJH. A 2-way analysis of variance

(ANOVA) with repeated measures was used to test the difference in mean vertical jump scores using FP and SP training modalities. Results showed a significant effect over time for vertical jump ($p < 0.001$). Moreover, a significant time by protocol interaction was noted ($p < 0.032$). A 1-way ANOVA demonstrated that only the SP group demonstrated improvements over time, in VJH, $p < 0.05$. The FP group did not improve statistically. The data from this study suggest that FP plyometric training did not have a significant effect on VJH and significant improvement in VJH was seen in subjects participating in SP plyometrics thus reinforcing the specificity principle of training. However, coaches should implement both types of plyometrics because both training modalities can improve power and quickness among basketball players.

Arabatzi et al. (2010) investigated the effects of an Olympic weight lifting (OL), a plyometric (PL), and combined weight lifting + plyometric (WP) training program on vertical jump (VJ) biomechanics. Thirty-six men were assigned randomly to 4 groups: PL group ($n = 9$), OL group ($n = 9$), WP group (), and control (C) group ($n = 8$). The experimental groups trained 3 d.wk, for 8 weeks. Sagital kinematics, VJ height, power, and electromyographic (EMG) activity from rectus femoris (RF) and medial gastrocnemius (GAS) were collected during squat jumping and countermovement jumping (CMJ) before and after training. The results showed that all experimental groups improved VJ height ($p < 0.05$). The OL training improved power and muscle activation during the concentric phase of the CMJ while the subjects used a technique with wider hip and knee angles after training ($p < 0.05$). The PL group subjects did not change their CMJ technique although there was an increase in RF activation and a decrease of GAS activity after training ($p < 0.05$). The WP group displayed a decline in maximal hip angle and a lower activation during the CMJ after training ($p < 0.05$). These results indicate that all training programs are adequate for improving VJ performance. However, the mechanisms for these improvements differ between the 3 training protocols. Olympic weight lifting training might be more appropriate to achieve changes in VJ performance and power in the precompetition period of the training season. Emphasis on the PL exercises should be given when the competition period approaches, whereas the combination of OL and PL exercises may be used in the transition phases from precompetition to the competition period.

Ebben et al. (2011) attempted to assess the kinetic characteristics of a variety of plyometric exercises. This study also sought to assess gender differences in these variables. Twenty-six men and 23 women with previous experience in performing plyometric training served as subjects. The subjects performed a variety of plyometric exercises including line hops, 15.24-cm cone hops, squat jumps, tuck jumps, countermovement jumps (CMJs), loaded CMJs equal to 30% of 1 repetition maximum squat, depth jumps normalized to the subject's jump height (JH), and single leg jumps. All plyometric exercises were assessed with a force platform. Outcome variables associated with the takeoff, airborne, and landing phase of each plyometric exercise were evaluated. These variables included the peak vertical ground reaction force (GRF) during takeoff, the time to takeoff, flight time, JH, peak power, landing rate of force development, and peak vertical GRF during landing. A 2-way mixed analysis of variance with repeated measures for plyometric exercise type demonstrated main effects for exercise type and all outcome variables ($p \leq 0.05$) and for the interaction between gender and peak vertical GRF during takeoff ($p \leq 0.05$). Bonferroni-adjusted pairwise comparisons identified a number of differences between the plyometric exercises for the outcome variables assessed ($p \leq 0.05$). These findings can be used to guide the progression of plyometric training by incorporating exercises of increasing intensity over the course of a program.

Makaruk et al. (2012) examined how focusing attention during nine weeks of plyometric training influence jumping performance. It was hypothesized that participants utilizing an external focus of attention during practice would produce greater improvements in jumping behavior compared to participants practicing in the internal and control conditions.Thirty-six untrained but physically active male college students were randomly assigned to 1 of 3 plyometric groups with a different focus of attention: external (EXF; N.=12), internal (INF; N.=12), and control (CON; N.=12). All participants subsequently participated in the same an 9-week periodized training program. Standing long jump (SLJ), countermovement jump (CMJ) and drop jump (DJ) were tested pre- and posttraining intervention.The EXF group exhibited greater improvement ($P<0.05$) in jumping distance for SLJ and height for CMJ than both the INF and CON groups, while the enhancement in jumping height for DJ was not superior ($P<0.05$) in the EXF group in comparison with the INF and CON groups.

However, the CON group showed a greater increase ($P<0.05$) in jumping height for DJ than the INF group. The EXF group increased the range of knee flexion (KF), whereas both the INF and CON groups decreased the KF during the CMJ. Additionally, only the CON group reduced KF during the execution of the DJ. The EXF group ($P<0.05$) increased contact time, whereas both the INF and CON groups decreased ($P<0.05$) contact time in DJ. The EXF group had significantly ($P<0.05$) greater vertical ground reaction force in CMJ and DJ when compared with the INF and CON groups.These results suggest that the external focus of attention during plyometric training may provide a greater stimulus to jump performance in slow stretch shortening cycle (SSC) tasks by producing greater force than adopting the internal and no specific focus.

Luebbers et al. (2003) examined the effects of 2 plyometric training programs, equalized for training volume, followed by a 4-week recovery period of no plyometric training on anaerobic power and vertical jump performance. Physically active, college-aged men were randomly assigned to either a 4-week (n = 19, weight = 73.4 +/- 7.5 kg) or a 7-week (n = 19, weight = 80.1 +/- 12.5 kg) program. Vertical jump height, vertical jump power, and anaerobic power via the Margaria staircase test were measured pretraining (PRE), immediately posttraining (POST), and 4 weeks posttraining (POST-4). Vertical jump height decreased in the 4-week group PRE (67.8 +/- 7.9 cm) to POST (65.4 +/- 7.8 cm). Vertical jump height increased from PRE to POST-4 in 4-week (67.8 +/- 7.9 to 69.7 +/- 7.6 cm) and 7-week (64.6 +/- 6.2 to 67.2 +/- 7.6 cm) training programs. Vertical jump power decreased in the 4-week group from PRE

(8,660.0 +/- 546.5 W) to POST (8,541.6 +/- 557.4 W) with no change in the 7-week group. Vertical jump power increased PRE to POST-4 in 4-week (8,660.0 +/- 546.5 W to 8,793.6 +/- 541.4 W) and 7-week (8,702.8 +/- 527.4 W to 8,931.5 +/- 537.6 W) training programs. Anaerobic power improved in the 7-week group from PRE (1,121.9 +/- 174.7 W) to POST (1,192.2 +/- 189.1 W) but not the 4-week group. Anaerobic power significantly improved PRE to POST-4 in both groups. There were no significant differences between the 2 training groups. Four-week and 7-week plyometric programs are equally effective for improving vertical jump height, vertical jump power, and anaerobic power when followed by a 4-week recovery period. However, a 4-week program may not be as effective as a 7-week program if the recovery period is not employed.