CHAPTER - II

REVIEW OF RELATED LITERATURE
The review of related literature for relating to the problem has been presented in this Chapter. The working bibliography was collected from the libraries of the Annamalai University, Annamalai Nagar, of the Alagappa University, Karaikudi, JIPMER, Pondicherry, Lakshmibai National Institute of Physical Education, Gwalior, Dr.Sivanthi Aditanar College of Physical Education, Tiruchendur and the Sports Authority of India, Nethaji Subash National Institute of Sports, Bangalore. The researcher also collected related information form the Internet Source.

Iain M. Fletcher\textsuperscript{53} to determine the effect of combined weight and plyometric programmes on golf drive performance. Eleven male golfers’ full golf swing was analyzed for club head speed (CS) and driving distance (DD) before and after an 8-week training program. The control group (n=5) continued their normal training, while the experimental group (n=6) performed 2 sessions per week of weight training and plyometrics. Controls

showed no significant \((p \geq 0.05)\) changes, while the experimental subjects showed a significant increase \((p<0.05)\) in CS and DD. The changes in golf drive performance were attributed to an increase in muscular force and an improvement in the sequential acceleration of body parts contributing to a greater final velocity being applied to the ball. It was concluded that specific combined weights and plyometrics training can help increases CS and DD in club golfers.

Heidi Rubenstein\(^{54}\) compare the effects of a four-week, general resistance training program (G) to a four-week, combined plyometrics and general resistance training program (GP) on shot speed on - goal (SS) in Division I Women's Soccer players. Eight members of the Manhattan College Women's Soccer Program (19-22 yrs) were randomly assigned to either G (n=4) or GP (n=4). Prior to and subsequent to training, each subject was tested for SS using radar (Sports Radar 3500). Briefly, subjects were asked to kick the ball (size 5, inflated to 6-1.01 atmospheres) maximally to a target 18ft away. Only trials that fell within 10-degree angle of trajectory relative to the device (visual inspection) were accepted as supported by the

manufactures manual. All subjects took a running start (3-4 steps). Three trials were averaged for each subject and the means were compared using dependent 't'-tests. Neither group improved significantly (p>.05), however GP showed trends (p=.06) favoring increased SS (47.4 ± 2.0 mph PRE vs. 48.0 ± 2.0 mph POST) while G decreased slightly (50.2 ± 4.9 mph PRE vs. 49.8 ± 2.8 mph POST).

**Fagan** Investigated with Nineteen males and fourteen females were randomly assigned to two training groups; maximum strength (85-90% 1 RM) and plyometrics, or maximum power (30% 1 RM jump squats) and plyometrics. Female competitive soccer players (N = 6) served as a control group. Training was given twice a week for 10 weeks. Both groups improved in lower body power and strength. Both forms of training were equally effective in increasing squat strength to perform plyometrics. However, sprint speed over distance of 5-40 meters did not change, therefore, this form of training was very specific and did not carry-over to a useful athletic pursuit. Strength training only has specific effects on the trained exercises.

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Sundaramoorthy conducted a study to find out the effects of isolated and combined weight and plyometric training on selected strength parameters, speed and power. Forty five men students studying Master's Degree in Physical Education at Dr.Sivanthi Aditanar College of Physical Education, Thiruchendur, were selected as subjects at random and were divided into three groups consisting of 15 subjects each. Group-I underwent weight training, Group II underwent plyometric training, Group III underwent combined weight and plyometric training. Arm strength, leg strength, explosive strength, strength endurance, speed and elastic power were selected as variables. The dip strength test, leg dynamometer, vertical jump, sit-ups, 50 metres run and bunny hops were administered to test the aforesaid variables separately. The results of the study indicated that arm strength, leg strength, explosive strength, strength endurance, speed and elastic power were improved significantly by weight training, plyometric training and combined weight and plyometric training programmers. No significant difference existed among weight training, plyometric training and combined weight and plyometric training groups in improving the selected dependent variables. The trend was in favour of combined

weight and plyometric training group for explosive strength, strength endurance, speed and elastic power whereas the trend was in favour of weight training group for arm strength and leg strength.

*Andres D.Lyttle et.al.*, examined the relative effectiveness of two leading forms of athletic training in enhancing dynamic performance in various tests. Thirty – Three men who participated in various regional level sports, but who had no previously performed resistance training, were randomly assigned to a maximal power training program, a combined weight and plyometric program or a non-training control group. The maximal power group performed weighted jump squats and bench press throws using a load that maximized the power output of the exercise. The combined group underwent traditional heavy weight training in the form of squats, and bench press and plyometric training in the form of depth jumps and medicine ball throws. The training consisted of two sessions a week for eight weeks. Both types of training groups were equally effective in enhancing a variety of performance measures such as jumping, cycling, throwing and lifting.

Wilson was performed in an effort to gain greater insights into the adaptations invoked by plyometric and weight training. Forty-one previously trained males were randomly allocated into a control, plyometric, or weight-training group. The experimental groups trained for 8 weeks, performing either heavy lifts or dynamic plyometric exercises. The following test items were performed prior to and at the completion of the training period: (a) vertical jump (b) a series of iso-inertial concentric and eccentric tests (c) push-up tests and (d) maximal bench press and squat lifts. Plyometric training significantly enhanced the rate of eccentric lower body force production. The weight-training group showed enhanced concentric function. These results were attributed to the specific stresses imposed by the differing forms of training and are discussed with reference to methods of enhancing training induced adaptations and the types of movements such training would tend to facilitate.

Maffiuletti et al. investigated the influence of a 4-week combined electro my stimulation (EMS) and plyometric training programme on the vertical jump performance of 10 volleyball


players. Training sessions were carried out three times weekly. Each session consisted of three main parts: EMS of the knee extensor muscles (48 contractions) EMS of the plantar flexor muscles (30 contractions), and 50 plyometric jumps. Subjects were tested before (week 0), during (week 2), and after the training programme (week 4), as well as once more after 2 week of normal volleyball training (week 6). Different vertical jumps were carried out, as well as maximal voluntary contraction (MVC) of the knee extensor and plantar flexor muscles. At week 2, MVC significantly increased (+20% knee extensors, +13% plantar flexors) as compared to baseline (<0.05). After the 4-week training programme, the different vertical jumps considered were also significantly higher compared to pre training (< 0.001), and relative gains were between 8-10% (spike counter movement jump) and 21% (squat jump). The significant increases in maximal strength and explosive strength produced by the training programme were subsequently maintained after an additional 2 weeks of volleyball training. EMS combined with plyometric training has proven useful for the improvement of vertical jump ability in volleyball players. This combined training (approximately 2 weeks) modality produced rapid increases of the knee extensors and plantar flexors maximal strength. These adaptations were then followed by an
improvement in general and specific jumping ability, likely to affect performance on the court. In conclusion, when EMS resistance training is proposed for vertical jump development, specific work out (e.g., plyometric) must complement EMS sessions to obtain beneficial effects.

Adams et al.\textsuperscript{60} conducted a study to investigate the effect of six weeks of squat, plyometric and squat plyometric training on power production. The purpose of this study was to compare the effectiveness of three training programmes Squat (S), Plyometric (P) and Squat-Plyometric (SP) in increasing hip and thigh power production as measured by vertical jump. Forty eight subjects were divided equally into 4 groups: ‘S’, ‘P’, ‘SP’ and control ‘C’. The subjects trained two days a week for a total of seven weeks which consisted of a week is technique learning period followed by six weeks of periodized ‘S’, ‘P’, or ‘SP’ training programmes. Hip and thigh power were tested before and after the training using the vertical jump test and the alpha level was set at .05. Statistical analysis of the data revealed a significant increase in hip and thigh power production, as measured by vertical jump in all three treatment groups. The ‘SP’ group achieved statistically greater improvement than the ‘S’ or ‘P’ groups. Examination of

the mean scores shows that the ‘S’ group increased 3.30 centimeters in vertical jump the ‘p’ group increased 3.81 centimeters and the ‘SP’ group increased 10.67 centimeters. The results indicate that the both ‘S’ and ‘P’ training are necessary for improving hip and thigh power production as measured by vertical jumping ability.

According to Wilson\(^61\) resistance training in the form of weight training and more recently, plyometric training are used as means to enhance the muscular strength and size, power, speed and endurance, enhance muscle tone, assist in rehabilitation and injury prevention, and to aid in the maintenance of muscular function.

C.J.Wilson\(^62\) determined which of three theoretically optimal resistance training modalities resulted in the greatest enhancement in the performance of a series of dynamic athletic activities. The three training modalities included (1) traditional weight training (2) plyometric training and (3) explosive weight training at the load that maximized mechanical power output.


Sixty-four previously trained subjects were randomly allocated to four groups that included the above three training modalities and a control group. The experimental groups trained for 10 weeks performing heavy squat lifts, depth jumps, or weighted squat jumps. All subjects were tested prior to training, after 5 weeks of training and at the completion of the training period. The test items included 1) 30-m sprint 2) Vertical jumps performed with and without a counter movement 3) maximal cycle test 4) iso-kinetic leg extension test, and 5) a maximal isometric test. The experimental group which trained with the load that maximized mechanical power achieved the best overall results in enhancing dynamic athletic performance recording statistical significant (P<0.05) improvements on most test items and producing statistically results superior to the two other training modalities on the jumping and iso-kinetic tests.

Reddy\textsuperscript{63} conducted a study on the effects of plyometric and weight training followed by plyometric training on power, speed, stride length and stride frequency, 45 boys were selected at random and put into one of the three groups (n=15). Group I underwent plyometric training, Group-II underwent plyometric

training followed by weight training and Group III (control) in their respective training programme. The subjects were tested for power, speed, stride length and stride frequency. Performance in power, speed, stride-length and stride frequency improved significantly for both plyometric and weight training followed by plyometric training when compared with the control group, and a non significant difference existed between the training groups.

Mc Bride\textsuperscript{64} examined the effect of an 8-week training programme with heavy-versus light-load jump squats on various physical performance measures and electromyography (EMG). Twenty-six athletic men with varying levels of resistance training experience performed sessions of jump squats with either 30% (JS 30, n = 9) or 80% (JS80, n = 10) of their one repetition maximum in the squat (1 RM) or served as a control (C, n = 7). An agility test, 20 metres sprint, and jump squats with 30% (30J), 50% (55J), and 80% (80J) of their 1 RM were performed before and after training. Peak force, peak velocity (PV), peak power (PP), jump height, and average EMG (concentric phase) were calculated for the jumps. There were significant increases in PP and PV in the 30J, 55J, and 80J for the JS30 group (p<or

The JS30 group also significantly improved in the 1 RM with a trend towards improved 20 metres sprint times. In contrast, the JS80 group significantly improved both PF and PP in the 55J and 80J and more 0'significantly in the 1 RM but ran significantly slower in the 20-m sprint. In the 30J the JS30 group's percentage increase in EMG activity was significantly different from that is the C group. In the 80J the J80 group's percentage increase in EMG activity was significantly different from that is the C group. This investigation indicates that training with light-load jump squats results in increased movement velocity capabilities and that velocity-specific change in muscle activity may play a key role in this adaptation.

Kubachka and Stevens investigated the effects of plyometric, strength training, and body weight exercises on the power, strength and endurance capacities of the trunk muscles were examined. Training sessions were arranged twice a week for five weeks (a total of 10 training sessions). Ploymetrics use two physiological properties of muscles, the stretch reflex and storage of elastic energy. When a rapid lengthening of a muscle occurs just prior to rapid shortening, a more powerful

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contraction results. Ploymetrics significantly improved power (8.6%) and strength (45.9%). Strength training increased power by 7.3% and strength by 82.5%. Body weight increased strength only by 21.9%. Polymetrics and strength training were both equally effective.

*Fatouros, et.al,*\(^6\) conducted a study to investigate the effect of polymetric training and weight training on force-power parameters of vertical jumping. For this purpose, thirty one male (20.1 + / -1.4 yrs) were subjects to determine if plyometric alone or in combination with weight training would increase force power parameters in vertical jump. Subjects were randomly assigned to either a plyometrics training (P) (n=11), weight training (wt) (n=10), or p+wt (pwt) (n=10) group. Training involved progressive intensity increase 60-85% of 1RM, three times a week for thirteen weeks. Dependent variables (Mean leg force, mean leg power and ground time) were compared prior to and after the training. All groups demonstrated significant changes as a result of the training. An ANCOVA was utilized since pre-training values were not similar at the starting of the training programme. Mean leg force increased 373 N for the 'PWT' group, 237 N for the 'P' group and 181 N for the 'WT'

group. The increases ranged from 17.5-42.6% average power increased 17 W/KG (PWT), 11.9 W/KG(P) and 11.5 W/KG(WT) which represents improvement of 23-40%. Average ground time decreased by 0.103 seconds, 0.067 seconds and 0.055 seconds for the ‘PWT’, ‘P’ and ‘WT’ groups respectively. ANCOVA revealed that ‘PWT’ training significantly increased force power parameters and decreased ground reaction time compared to both ‘WT’ and ‘P’. These results suggest that plyometrics in conjunction with weight training can produce greater gains in vertical jumping compared to plyometrics or weight training alone.

*Sethu*\(^{67}\) examined the effect of maximal power training on speed, explosive power and leg strength of college athletes. Twenty four subjects for this study were selected from Dr.Sivanthi Aditanar College of Physical Education Tiruchendur randomly and divided into two groups as experimental and control groups. Data was collected from each subject before and after the maximal power training. The collected data was statistically analysed by using analysis of covariance (ANCOVA). It was found that there was significant difference in speed, power

and leg strength of the maximal power training group when compared to those of the control group.

Rajasekaran\textsuperscript{68} conducted a study to find out the effect of maximum strength and speed training in series and parallel on elastic strength components among male students of Physical Education and Sports. Forty five students were selected at random and were divided into three groups. Group I underwent series training, Group II underwent parallel training and Group III acted as control. Speed, explosive power, stride frequency, leg strength, back strength and anaerobic capacity were selected as variables. To assess speed, explosive power, leg strength and back strength and anaerobic capacity, 50 metres run, Sargent Jump and standing broad jump, leg lift with dynamometer and Margaria-kalamen tests were administered. The results of the study indicated that the series training and parallel training groups had significantly improved on speed, explosive power, stride frequency, leg strength, back strength and anaerobic capacity when compared with the control group. The parallel training group had significantly improved speed, stride frequency, explosive power and anaerobic capacity when

compared with series training group. The leg strength and back strength showed no significant difference between series and parallel groups. However the increase in leg strength was in favour of the parallel group.

According to Bendict\textsuperscript{69} Maximum strength is the capacity to generate force within an isometric contraction. It is a valuable attribute to most athletes because it acts as a general base that supports specific training in other spheres of conditioning. Resistance training program variables can be manipulated to optimize maximum strength. After deciding on the exercises appropriate for the sport, the main variables to consider are training intensity (load) and volume. The other factors that are related to intensity are loading form, training to failure, speed of contraction, psychological factors, interest recovery, order of exercise, and number of sessions per day. Repetitions per set, sets per session, and training frequency, together constitute training volume. In general, maximum strength is best developed with 1-6 repetitions of maximum loads, a combination of concentric and eccentric muscle actions, 3-6 maximal sets per session, training to failure for limited periods, long interest recovery time, 3-5 days of training per week, and dividing the

day's training into 2 sessions. Variation of the volume and intensity in the course of a training cycle will further enhance strength gains. The increase in maximum strength is affected by neural, hormonal and muscular adaptations. Concurrent strength and endurance training, as well as combination strength and power training, will also be useful.

*Helgrud*\(^7\) investigate the effects of maximal, upper-body, skill-related strength training on the work economy and anaerobic threshold of double-polling ski ergometry were investigated in female cross-training Skiers (N=15). A high-intensity strength training group (N=8) and a non-strength training group (N=7) participated for nine weeks during which predominantly endurance work (running, roller skiing, and then skiing) was performed. Strength training was performed 3 days per week. Work economy, but not anaerobic threshold, improved significantly in the strength-trained group. Time to exhaustion improved significantly for both groups with the strength being significantly more than that in the control group.

A study was conducted by Savari Rajan on the “Effect of maximal power Training on power related fitness variables”. For the purpose of the study, thirty men students from the Department of Physical Education and Sports sciences, Annamalai University, Annamalai Nagar, Tamil Nadu, and India were selected as subjects at random. The selected subjects were divided into two equal groups of fifteen subjects each maximal power training group and control group. The experimental group underwent maximal power training for three days per week for twelve weeks. Power variables such as explosive power in terms of vertical explosive power in terms of horizontal, elastic power and anaerobic power were selected as criterion variables. The data were collected prior to and immediately after the training programme. The analysis of covariance was used to analyze the data of the maximal power training group and the control group. The results of the study showed that there was no significant difference between maximal power training group and control group.

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Hoff and Almasbakk examined the effect of maximum strength bench-press training combined with normal team skill training in handball was investigated. The subject’s female team-handball players from the Norwegian second division were randomly divided into a training group (TG) that participated in normal handball training plus maximal heavy progressive resistance training with free weights, and a control group (CG) that underwent handball training only. Dependent variables were standing-throw velocity, throwing velocity with a 3-step run-in-set shot, and one repetition maximum (1-RM) in the bench press. The TG improved significantly in all variables (bench press; 41.6 to 55.1 kg; standing throw, 19.8 to 3.3 m). Whereas CG had significant improvements in the throwing variables only (standing throw, 18.5 to 21.1 m. running throw, 22.6 to 24.6 m/sec). The TG had significantly greater improvement than the CG in the bench press and throwing velocity with a 3-step run-in.

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Kalimuthu\textsuperscript{73} conducted a study to find out the relative effect of power training with varied intensities on speed, explosive power in horizontal and vertical terms and elastic power of University men students. To achieve the purpose of this study, forty five men students were selected from Department of Physical Education and Sports Science, Annamalai University, and they were divided into three equal groups of fifteen each. Group I underwent power training with high intensity, Group II underwent power training with low intensity and Group III acted as the control. The selected subjects were tested on the selected criterion variables such as speed, explosive power in horizontal and vertical terms and elastic power prior to and immediately after the training programme. The results of the study indicated that speed, explosive power in horizontal and vertical terms and elastic power were improved significantly due to power training with high intensity programme. No significant improvement on selected criterion variables such as explosive power vertical term and elastic power due to power training with low intensity programme.

Kammier\textsuperscript{24}, conducted a study on effects of single vs. multiple-set resistance training on maximum strength and body composition in trained postmenopausal women. The purpose of this study was to examine the effect of a single vs. a multiple-set resistance training protocol in well-trained early postmenopausal women, Subjects (N = 71) were randomly assigned to begin either with 12 weeks of the single-set or 12 weeks of the multiple-set protocol. After 5 weeks of re-generational resistance training, the subgroup performing the single-set protocol during the first 12 weeks crossed over to the 12-week multiple-set protocol and vice versa. Neither Exercise type exercise intensity, degree of fatigue, rest periods, speed of movement, training sessions per week, compliance and attendance, or periodization strategy in did not differ between exercise protocols. Body mass, body composition, and 1 repetition maximum (1RM) values for leg press, bench press, rowing, and leg adduction were measured at baseline and after each period. Multiple-set training resulted in significant increases (3.5-5.5\%) for all 4 strength measurements, whereas single-set training resulted in significant decreases (-1.1 to -2.0\%). Body mass and body composition did not change

during the study. The results show that, multiple-set protocols are superior to single-set protocols in increasing maximum strength.

Harris\textsuperscript{75}, conducted a study on, the effect of resistance-intensity on strength-gain response in older adults. This study examined how training intensity affects strength gains in older adults over an 18-week training period using non-periodized, progressive resistance-training protocols. Untrained men and women participants were separated into 4 groups: group A (n=117, 71.4 ± 4.6 years) performed 2 sets of 15 repetitions maximum (RM), group B (n=13, 71.5 ± 5.2 years) performed 3 sets of 9 RM, group C (n=17, 69.4 ± 4.4 years) performed 4 sets of 6 RM, group D (n=14, 72.3 ± 5.9 years) served as controls. Training groups exercised 2 days/week performing 8 resistance exercises. Except for training intensity, the acute program variables were equated between groups. A 1RM for 8 exercises was obtained every 6 weeks. The total of 1 RM for the 8 exercises served as the dependent variable. Repeated measures of analysis of variance (ANOVA) and Scheffe post hoc revealed that, at 6 weeks, only groups B and C were significantly stronger.

than group D (p<0.01). By weeks 12 and 18, all training groups were significantly stronger than controls (p<0.01). However, no difference existed between groups A, B and C at any time. The data suggests that, for protocols with equated acute program variables, strength gain is similar over 18 weeks for training intensities ranging from 6 to 15 RM in previously untrained older adults.

Cronin and M. Henderson\textsuperscript{76} conducted a study on maximal strength and power assessment in novice weight trainers. The purpose of this study was to investigate whether changes in maximal strength and power output occurred over time in the absence of strength and power trainings in novice weight trainers. It also investigated whether differences existed between upper-and lower-body assessments and unilateral and bilateral assessments. The power output and maximal strength [(1 repetition maximum (1 RM)] of 10 male novice subjects were measured on 4 occasions, each assessment being 7-10 days apart. The exercises used to measure the upper-and lower-body strength and power outputs were the bench press and supine squat, respectively. Significant (p<0.05) changes in unilateral (9.8–16.8\%) and bilateral 1 RM (6.8–15.0\%) leg strength were

found, the first assessment being significantly different from all other assessments and assessment 2 significantly different from assessment 4. Changes in the upper body (10–13.6%) were also observed. The only significant difference was between assessment 1 and the other testing occasions. No differences in power output were observed for both the upper and lower body during the study. It would seem that considerable changes in maximal strength occur rapidly and in the absence of any formal strength training programs in novice weight trainers.

Amandam determined whether a 6-week regimen of plyometric training would improve running economy (i.e., the oxygen cost of sub maximal running). Eighteen regular but not highly trained distance runners (age = 29 ± 7 [means ± SD] years) were randomly assigned to experimental and control groups. All subjects continued regular running training for 6 weeks; experimental subjects also did plyometric training. Dependent variables measured before and after the 6-week period were economy of running on a level treadmill at 3 velocities (women : 2.23, 2.68, and 3.13 m.s⁻¹; men: 2.68, 3.13 and 3.58 m.s⁻¹), \( O_{2\text{max}} \), and indirect indicators of ability of muscles of lower limbs to store and return elastic energy. The

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last were measurements during jumping tests on an inclined (20°) sled: maximal jump height with and without countermovement and efficiencies of series of 40 sub maximal countermovement and static jumps. The plyometric training improved economy (p<0.05). Averaged values (m.m⁻¹.kg⁻¹) for the 3 running speeds were: (a) experimental subjects -5.14± 0.39 (pre-training) and 5.26 ±0.39 (post-training); and (b) control subjects -5.10 ± 0.36 (pre training) and 5.06 ± 0.36 (post training). The O₂max did not change with training. Plyometric training did not result in changes in jump height or efficiency variables that would have indicated improved ability to store and return elastic energy. We conclude that 6 weeks of plyometric training improves running economy in regular but not highly trained distance runners.

Masamoti ⁷⁸ examines the acute effects of plyometric exercise on 1 repetition maximum (RM) squat performance in trained male athletes. Twelve men (mean age ±SD: 20.5± 1.4 years) volunteered to participate in 3 testing sessions separated by at least 6 days of rest. During each testing session the 1 RM was assessed on back squat exercise. Before all 3 trials subject

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warmed up on a stationary cycle for 5 minutes and performed static stretching. Subjects then performed 5 sub maximal sets of 1-8 repetitions before attempting a 1 RM lift. Subjects rested for at least 4 minutes between 1 RM trials. During the first testing session (T1) subjects performed a series of sets with increasing load until their 1 RM was determined. During the second and third testing sessions subject performed in counterbalanced order either 3 double-leg tuck jumps (TJ) or 2 depth jumps (DJ) 30 seconds before each 1 RM attempt. The average 1 RM lifts after T1 and testing sessions with TJ or DJ were 139.6 ± 29.3 kg, 140.5 ± 25.6 kg, and 144.5 ± 30.2 kg, respectively (T1<DJ; p<0.05). These data suggest that DJ performed before 1 RM testing may enhance squat performance in trained male athletes.

*Mikel Izquierdo et.al,* conducted a study on the effects of a 16-week progressive strength-training program on blood lactate accumulation (LA), maximal workload (W_max) attained during progressive cycling exercise, maximum half-squat (1 RM_HS), muscle cross-sectional area of the quadriceps femoris muscle group (CSAQF), and serum hormone concentrations were

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examined in 11 middle-aged (46 year old [M 46]) and 11 older (64 year old [M64]) men. During the 16 weeks of training, significant increases were observed in 1 RM HS in M46 and M64 (41–45%; p<0.001). The muscle CSAQF increased (13–11%; p>0.01) for both groups. The first 8 weeks of training led to significant increases in $W_{\text{max}}$ (6–11% p<0.001) and decreases in sub maximal (LA) in both groups, but no further training-induced changes were observed during the subsequent 8 weeks of training. Statistically significant relationships were observed in M64 and in the combined group M46 + M64 between the training-induced changes observed in $W_{\text{max}}$ and serum testosterone-cortisol and free – testosterone – cortisol ratios, whereas in M46 the respective correlation values did not reach statistically significant levels. These data indicate that strength training results in a significant improvement in maximal and sub maximal endurance during the first 8 weeks of strength training in both age groups, related in part to the intensity and the volume of resistance training used and to the training status of the subjects. The relationships found in this study between various indices of cycling testing and serum hormone concentrations after strength training suggest that maximal incremental cycling might be used as an additional test to detect
anabolic catabolic responses to prolonged strength training in middle-aged and older men.

According to Jeffrey⁸⁰ changes in muscle power output and fiber characteristics following a 3 d.wk⁻¹, 8 week plyometric and aerobic exercise program. Were specified in male subjects (n=19) were randomly assigned to either group 1 (plyometric training) or group 2 (plyometric training and aerobic exercise). The plyometric training consisted of vertical jumping, bounding, and depth jumping. Aerobic exercise (at 70% maximum heart rate) was formed for 20 minutes immediately following the plyometric workouts. Muscle biopsy specimens were collected from the muscles vastus lateralis before and after training. Type I and type II fibers were identified and cross-sectional areas calculated. Peak muscle power output, measured using a countermovement vertical jump, significantly increased from pre training to post training for group 1 (2.8%) and group 2 (2.5%). Each group demonstrated a significant increase in fiber area from pre training to post training for type 1 (group 1, 4.4%; group 2, 6.1%) and type II (group 1, 7.8%; group 2, 6.8%). Following plyometric training, there is an increased power output that may in part be related to muscle fiber size.

Conroy conducted a study to investigate plyometric training and its effects on speed, strength and power of inter-collegiate athletes. Twenty-one female and thirty male track / field athletes at Ohio Northern University served as subjects. The subjects were divided by gender and track group (power or endurance) and randomly assigned to either an experimental group which participated in plyometric training or a control group which did not perform any of these drills. The experimental group trained three times per week with each session lasting 20-40 minutes. Each subject was tested three times during the 14 week study. A repeated measures analysis of variance with three between factors and one within factors was used in comparing the variables among the groups for pre-test mid-test and post-testing periods. The between factors were gender (males/females) track group (power/endurance) and treatment group (control / experimental) and the within factor was the three test periods. A total of six assessment tests were administered. The skin fold measurement showed a four-way interaction between gender (males greater than females), between test periods (post test greater than pre-test) between

track group (power greater than endurance) and between control and experimental groups. No other test demonstrated any significant differences between the groups. The 40 yard-dash showed a three-way interaction for the experimental group between gender and between track groups. The test for flexibility also showed a three-way interaction between test period between gender and between track groups. Iso-kinetic testing for power (180, 240 and 300 degrees) and the standing long jump showed a significant result for gender and track group. Iso-kinetic testing for strength (60 degrees) and the vertical jump test showed significant results for gender test period and track group. No other significant results were found.

Rimmer and Sleivert\textsuperscript{82} studied the effects of sprint-specific plyometric programme on sprint performance; in 8-week training study consisting of 15 training sessions was conducted. Twenty six male subjects completed the training. A plyometrics group (N=10) performed sprint-specific plyometric exercises, while a sprint group (N=7) performed sprints. A control group (N=9) was included. The subjects performed sprints over 10 and 40 metres distances before (pre) and after (post) training. For the plyometric group, significant decreases in time occurred over

the 0-10 metres. (pre 1.96 ± 0.10 sec, post 1.91± 0.08 sec, p=0.001) and 0-40 metres. (pre = 5.63 ± 0.18 sec, post = 5.53 ± 0.20 sec, p=0.001) distances, but the improvements in the sprint were not significant over either the 0-10 metres. (pre 1.95 ± 0.06 sec, post 1.93 ± 0.05 sec) or 0-40 metres distance (pre 5.62 ± 0.14 sec, post 5.55± 0.10 sec). The magnitude of the improvements in the plyometric training group was not however significantly different from that the in sprint group. The control group showed no changes in sprint times. There were no significant changes in stride length or frequency, but ground contact time decreased at 37 metres by 4.4% in the plyometrics group only. It is concluded that sprint specific plyometric programme can improve 40 metres sprint performances to the same extent as standard sprint training, possibly shortening ground contact time.

Kraemer et.al.,\textsuperscript{83} examined the effects of sprint/plyometric training with the Meridian Elite-style shoe on various performance parameters. Seventeen healthy men were randomly assigned to either an athletic-shoe training group (AS) or a meridian elite-shoe training group (MS). Both the groups

participated in an eight week training programme consisting of weight training and sprint/ plyometric training. Anthorpometry, muscular strength, speed, power and rate of power development assessments were performed prior and after training. Both the groups demonstrated similar increases in 1RM squat and bench press, power output, and rate of force development during jumping. Both the group’s demonstrated similar improved 40-yard dash times, but the MS group showed greater improvement in 60-yards dash times (4 Vs 2% respectively). The MS group significantly increased their vertical jump height, whereas only a trend \( p = 0.08 \) for improvement was observed in the AS group. Rate of sub maximal force development of the plantar flexor muscles in the dorsi flexed position improved to a greater extent in the MS group. Compared to two previous studies, this newly designed model of strength shoe showed a lower incidence of pain and injury. In conclusion, the results of the study indicated that the Meridian Elite shoes may have an ergogenic effect on performance when used during eight weeks of sprint / plyometric training.
Gehri et al.,\textsuperscript{84} conducted a study to determine which plyometric training technique is the best for improving vertical jumping ability, positive energy production and elastic energy utilization. Data were collected before and after 12 weeks of jump training and were analysed by ANOVA. Subjects (n = 28) performed jump under 3 testing conditions, squat jump, counter movement jump and depth jump. This study proves the efficiency to including plyometric depth jump training as part of the athlete's overall programme for improving vertical jumping ability and concentric contractile performance.

Holcomb\textsuperscript{85} et al., studied the effectiveness of modified plyometric programmes on power and vertical jump. 51 college men were selected as subjects and they were put into modified plyometric depth jump programme (n=10), a counter movement jump programme (n=10), a weight training programme (n=12), and a conventional plyometric DJ programme (n=10) and a control group (n=9). Subjects underwent pre and post testing to determine power and VJ height. The test jumps were the counter movement jump (CMJ) and static jumps (SJ).


subjects trained 3 days a week for 8 weeks. All groups improved in both peak power and VJ, for CMJ, the peak power increased in all the training groups. No significant differences were found for power and VJ height among the training groups.

*Stroupe* investigated the effects of a jump-training involving instruction in jumping mechanics, plyometric training, and flexibility exercises were assessed on the jumping performance and mechanics of keen function in female (N=11) high school volleyball players. Training was performed three times a week for two hours per day over six weeks. A group of untrained males matched for physical structure served as a control group.

Landing forces decreased, vertical jump increased, and knee mechanics improved after the training program. There was no way of attributing these improvements to any one part of the complex training program (technique, plyometrics, flexibility). Since a total of 18 sessions were experienced and yielded significant changes, it is likely that technique training (neurological reorganization) has a substantial effect on the athletes' performances. Flexibility did not change through training.

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Schwendel\textsuperscript{67} conducted a study on traditional baseball weight training versus power weight training effects on bat velocity. Subjects were sixty male and female college students, ranging in age from 18 to 28 years. The training programme exercises were the leg press, leg curl, leg extension, bench press, pull down, military press, bicep curl, and tricep extension, and performed on universal weight extension, bench machines. Initial and final bat velocities were measured for all sixty subjects and subjects in the experimental groups were tested for a 1 RM in the training programme exercises. The traditional groups (3 x 10) performed each eccentric contraction in four seconds. The power groups executed each repetition in one second and trained according to the principles of periodisation. Both groups trained for seven weeks. The results suggest that power trained males made greater improvements in bat velocity than any other groups. Females made greater improvements in upper and lower body strength than males while traditional training and power training equally enhanced lower body strength.

According to James et.al., evidence indicates that leg weakness in older adults is associated with decreased control of balance. The gender-specific implications of strength training on control of balance in older men and women remains unknown. This study examined the initial adaptations to 12 weeks of low-volume, single-set-to-failure strength training and its effect on quadriceps strength and control of multidirectional balance in previously untrained older men (n=11) and women (n=11) 59-83 years of age. Leg strength increased 23-30% (p<0.001) across genders; however, the effect on balance varied between genders. No significant changes were noted in the women, whereas 37% (p<0.014) more sway in the medial-lateral direction was noted in the men, with no change in the anterior-posterior direction. These results demonstrate that this training protocol may not be effective for improving balance and may lead to worsening of balance in older men.

Fincher evaluated the effect of a single-set, high-intensity resistance-training program on gains in the times that collegiate football players were able to maintain a constant power output.
that stressed anaerobic energy systems. Ss (N = 40) were randomly assigned to a single-set high-intensity maximally-exhaustive training group (~6-10 repetition) or a traditional multiple-set group (3 sets of 6-10 RM). The multiple-set group did not attempt extra lifts to achieve maximum exhaustion. Training lasted 10 weeks. Gains in time before failure for upper and lower body exercises improved significantly for both groups. The one-set high-intensity group gained significantly more than the multiple-set group.

Hetzler\(^9\) examined two groups of 10 prepubescent and pubescent male baseball players trained three times per week for 12 weeks using a variety of general free-weight and machine exercises designed for both strength and power acquisition. One group was experienced in strength training while the other comprised novices. A comparable control group (N=10) did not perform the training program but did participate in all other non-experimental activities.

For the experienced, novice, and control groups respectively, the following gains were recorded: leg press -41%, 40% and 14%; and bench press -23%, 18% and 0%. Both

training groups were significantly better than the control group. Similarly, the two training groups improved in vertical jump. However, the control group improved to a significantly greater degree in peak and mean anaerobic power and the 40-yard dash.

The training regime improved the training activities but did not transfer them to functional performance measures. One could argue that the training actually caused anaerobic power and 40-yard dash measure to decrease, particularly in the experienced strength-training group. The metabolic changes in training groups did not transfer changes in energy potential to dynamic cycling, supporting the principle of specificity. In particular, the high force/low velocity aspects of the training did not transfer to high velocity activities.

Starkey et al., determined the effects of different volumes of high-intensity resistance training on isometric torque and muscle thickness. Training was conducted three times per week using set (group N=18) or three sets (group N=20) of exercise. A control group (N=10) performed no exercise of the experimental form. Both groups improved torque similarly at

most angles. There were no significant differences in muscle thickness changes.

**Hass et.al.**[^2] find out the effects of low volume strength training and high volume strength training on strength and endurance development in resistance trained adults (N = 40) were determined. Subjects were assigned to a group undergoing experimental training consisting of either one or three sets of 8-12 repetitions to failure, three times per week for 13 weeks. Performance gains were measured through 1 RM for leg extension, leg curl, chest press, overhead press, and biceps curl. Muscular endurance was measured for chest press and leg extension as the number of repetitions to failure with a load of 75% of baseline 1RM. Both groups achieved increased strength and muscular strength with no differences between them on any measure.

**Gallagher et.al**[^3] evaluated a low-volume, high-intensity strength training program's effect on the preservation of knee extension and plantar flexor strength and size in response to


unloading. Males underwent 21 days of unilateral lower limb suspension and were assigned to a no exercise (N=4) or countermeasures (N=4) groups. Countermeasure training occurred every third day over the 21-day period. It consisted of two maximal isometric contractions, 1 set of 10 concentric and eccentric isotonic repetitions, and one set to exhaustion at 80% of original 1 RM. All measures of strength declined in the control group. The counter measure training group showed no decline in any factors. Muscle strength and size was preserved during the unloading period using a low-volume, high-intensity resistance program every third day.