Chapter II

REVIEW OF RELATED LITERATURE

The review of related literature of the present problem has been presented in this chapter. The working studies included were collected from the libraries of the Annamalai University, Annamalai Nagar, Alagappa University, Karaikudi, Dr.Sivanthi Aditanar College of Physical Education, Tiruchendur, Tamil Nadu Sports University and The Sports Authority of India, Chennai, and Nethaji Subash National Institute of sports, Bangalore. The researcher also collected related information from the Internet Source.

Resistance and endurance training are often performed concurrently in most exercise programs and in rehabilitative settings in an attempt to acquire gains in more than one physiologic system. However, it has been proposed that by simultaneously performing these two modes of exercise training, the strength gains achieved by resistance training alone may be impaired. Thus, the aim of this study was to compare the effects of 16 weeks of resistance training and concurrent resistance and endurance training on muscular strength development in 38 sedentary, apparently healthy males (25 yr 6 8 mo). Subjects were age-matched and randomly assigned to either a control (Con) group (n = 12), resistance training (Res) group (n = 13), or concurrent resistance and endurance training (Com)
group (n = 13). After 16 weeks, no changes were found in the strength of the subjects in the Control group. Resistance training and concurrent resistance and endurance training significantly (p < 0.05) improved strength in all of the eight prescribed exercises. The data also indicated that 16 weeks of concurrent resistance training and endurance training was as effective in eliciting improvements in strength as resistance training alone in previously sedentary males. As such, concurrent resistance and endurance training does not impede muscular strength gains and can be prescribed simultaneously for the development of strength in sedentary, apparently healthy males and thus may invoke all the physiologic adaptations of resistance and endurance training at once Brandon, Shaw and Gregory (2009).

Goran Sporis, Lana Ruzic and Goran Leko, (2008) compared changes in anaerobic endurance in elite First-league soccer players throughout two consecutive seasons, in two phases, with and without high-intensity situational drills. Eighteen soccer players were tested before and after the eight-week summer conditioning and again in the next season. The measured variables included 300-yard shuttle run test, maximal heart rate, and maximal blood lactate at the end of the test. During the first phase of the study, the traditional sprint training was performed only 2 - 3 weeks and consisted of 15 bouts of straight-line sprinting. In the second year the 4-3-4 min.
drills at an intensity of 90–95% of HR max, separated by periods of 3-minute technical drills at 55–65% of HR max were introduced. Statistical significance was set at $P \leq 0.05$. The traditional conditioning program conducted during the first year of the study did not elicit an improvement in anaerobic endurance as recorded in the 300-yard shuttle run test. After the intervention, the overall test running time improved significantly ($55.74 \pm 1.63$ s vs. $56.99 \pm 1.64$ s; $P < 0.05$) with the maximal blood lactate at the end of the test significantly greater ($15.4 \pm 1.23$ mmol-L$^{-1}$ vs. $13.5 \pm 1.12$ mmol-L$^{-1}$, $P < 0.01$). As a result, this study showed some indication that situational high-intensity task training was more efficient than straight-line sprinting in improving anaerobic endurance measured by the 300-yard shuttle run test.

**Rhea, et. al., (2008)** developed evidence-based training programs rely on several training principles demonstrated through research and professional experience. In an effort to further research examining these principles, an investigation was designed and completed to evaluate the compatibility of cardiovascular endurance and neuromuscular power training. Sixteen Division-I collegiate baseball players were divided into two training groups with lower body power measured before and after their college playing season. The two groups differed in training in that one group performed moderate to high-intense cardiovascular endurance training 3–4 days
per week throughout the season, while the other group participated in speed/speed endurance training. A significant difference between groups (P < .05) was identified in the change in lower body power during the baseball season. During the season, the endurance training group decreased an average of 39.50 ± 128.03 watts while the speed group improved an average of 210.63 ± 168.96 watts. These data demonstrate that moderate- to high-intense cardiovascular endurance and neuromuscular power training do not appear to be compatible when performed simultaneously. For baseball players, athletes who rely heavily on power and speed, conventional baseball conditioning involving significant amounts of cardiovascular endurance training should be altered to include more speed interval training.

**Víctor, et. al., (2008)** designed to increase strength and aerobic endurance in one season was tested on 16 professional soccer players from Spain with a mean age of 28 ± 3.37 years. The schedule comprised four macro cycles of 12 weeks of aerobic endurance and strength training. As much for the strength training as for the aerobic endurance, the program used a sequence of general, special and specific exercises. Assessments were made with routine tests (i.e., squat jumps [SJs], countermovement jumps [CMJs], and countermovement jumps with arm swing [CMJ]) at the end of each macro cycle, and the Post test was used to assess aerobic endurance.
as a function of running speed and distance, at the start and end of the training schedule and at the start of the third macro cycle. Jumps were performed on an infrared platform fitted to the Muscle Lab system. The Post test showed differences between the first evaluation and the second and third evaluations: 3,550 ± 411.59 m vs. 2,006 ± 207.20 m (P < 0.01). For 2 of the 3 jumps analyzed, the results were better in the last 2 than in the first 2 evaluations (SJ, 43.13 ± 3.77 vs. 39.47 ± 3.4 [P < 0.05]; CMJ, 49.80 ± 3.77 vs. 46.67 ± 3.76 [P < 0.05]; CM Jas, 56.24 ± 5.2 vs. 52.98 ± 4.54 [P > 0.05]).

Improvement of aerobic endurance was produced on the first phase of the season as a consequence of the training. To increase strength, it is necessary to augment the number of training sessions of this type. It is convenient to separate aerobic endurance and strength training to create more ample blocks during the last two macro cycles.

Daniel Baker, (2003) investigated the effect on upper-body power output of manipulating resistances using contrast or complex power training. This power-training strategy typically entails the athlete alternating sets of a heavy resistance in a strength-oriented exercise with sets of lighter resistances in a power-oriented exercise. Sixteen rugby league players, who were experienced in power training and who performed complex training on a regular basis, served as subjects for this study and were divided equally into a control (con) or experimental (exp) group. Both groups were pre and post tested for
power output while performing explosive bench press throws in a smith machine with a resistance of 50 kg (bt p50). The exp. group performed an intervention strategy of a 6-repetition set of bench presses with a resistance of 65% of 1 repetition maximum (65% 1rm) between tests. At the pretest occasion, no differences were observed between the groups in power output; however, at the post testing, a significant difference in power output was observed between the groups in the bt p50. The 4.5% increase in the power output recorded during the post testing bt p50 for the exp. group was determined to be significantly different from all other scores (p ≠ 0.05). These data indicate that the performance of a set of heavy resistance strength training exercise between power training sets will acutely enhance power output in the second power training set. This effect has been previously theorized as possibly due to some combination of acute neural or mechanical adaptations.

Lesley, et. al. (2003) examined whether substituting 50% of run training volume with cycling (cross training) would maintain 3,000-m race time and estimated VO₂ max in competitive female distance runners during a five-week recuperative phase. Eleven collegiate runners were randomly assigned to either the run training–only (R) group (n=6) or the cycle training (R/C) group (n=5), which cross trained on alternate days. The groups trained daily at a reduced intensity (75–80% of maximum heart rate). Training volume was
similar to the competitive season (40–500 mi·wk\(^{-1}\)) except that cycling represented 50% of volume for the R/C group. On follow-up, 3,000-m time was 1.4% (9 second) slower in the R group and 3.4% (22 second) slower in the R/C group. No important change in estimated VO\(_2\) max was found for either group. It was concluded that cycle cross training adequately maintained aerobic performance during the recuperative phase between the cross country and track seasons, comparable to the primary sport of running.

*Michael, et al., (1998)* Twenty well-trained runners (\(\dot{V}O_2\)\(_{\text{max}}\) 4.6 ± 0.5 L·min\(^{-1}\)) were age and ability matched and assigned to either a cross training (CT) or run only group (RT). All subjects maintained normal running distance and intensity for 6 wk and reported for three additional training sessions per week. These workouts were performed outdoors on a 400-m track or measured road course (RT) or on a bicycle ergometer (CT). The sessions were as follows: (work:rest\(^{-1}\) ratio = 1): 5 × 5 min at >95% \(\dot{V}O_2\)\(_{\text{max/peak}}\) (Monday), 50-60 min at 70\%\(\dot{V}O_2\)\(_{\text{max/peak}}\) (Wednesday), and 3 × 2.5 min at >105\%\(\dot{V}O_2\)\(_{\text{max/peak}}\), plus 6 × 1.25 min at >115\%\(\dot{V}O_2\)\(_{\text{max/peak}}\) (Friday). Subjects were tested before (PRE), after three week (MID), and after six week (POST) of intensified training. Blood samples were obtained from RT, CT, and ten controls (CON) at each time point (0600 h). Runners also completed a 10-min submaximal run at the same absolute intensity (velocity to elicit 75\% of initial \(\dot{V}O_2\)\(_{\text{max}}\))
during which the heart rate, RPE, and \( \dot{V}O_2 \) were measured. Each runner then completed a simulated 5-km race (time trial) on a treadmill. Total testosterone (TT), free testosterone (FT), cortisol (C), and creatine kinase activity (CK) were determined. Running economy was similar between RT and CT; however, RPE decreased significantly at MID and POST compared with that at PRE (\( P < 0.05 \); time effect). There were no significant differences among groups for TT, FT, or CK, but C was significantly lower in CON than in RT and CT. Performance was significantly faster (\( P < 0.05 \); time effect) in the 5-km race at MID (1076.1 ± 81.4 s) and POST (1068.6 ± 83.9) compared with PRE (1096.6 ± 79.5) but was not different between CT and RT. In conclusion, RT and CT responded similarly to 6 wk of increased training, and both groups improved 5-km performance to a similar extent.

*Mujika, Santisteban and Castagna (2009)* examined the effects of two in-season short-term sprint and power training protocols on vertical countermovement jump height (with or without arms), sprint (Sprint-15m) speed and agility (Agility-15m) speed in male elite junior soccer players. Twenty highly trained soccer players (age 18.3 ± 0.6 years, height 177 ± 4 cm, body mass 71.4 ± 6.9 kg, sum skinfolds 48.1 ± 11.4 mm), members of a professional soccer academy, were randomly allocated to either a Contrast (\( n = 10 \)) or Sprint (\( n = 10 \)) group. The training intervention consisted of six
supervised training sessions over seven weeks, targeting the improvement of the players' speed and power. Contrast protocol consisted of alternating heavy-light resistance (15-50% body mass) with soccer-specific drills (small-sided games or technical skills). Sprint training protocol used line 30-m sprints (2-4 sets of 4 × 30 m with 180 and 90 seconds of recovery respectively). At baseline no difference between physical test performances was evident between the two groups (P > 0.05). No time × training group effect was found for any of the vertical jump and Agility-15m variables (P > 0.05). A time × training group effect was found for Sprint-15m performance with the Contrast group showing significantly better scores than the Sprint group (7.23 ± 0.18 vs. 7.09 ± 0.20 m·s⁻¹, P < 0.01). In light of these findings Contrast training should be preferred to line sprint training in the short term in young elite soccer players when the aim is to improve soccer-specific sprint performance (15 m) during the competitive season.

McBride, et al., (2009) examined four different methods of calculating volume when comparing resistance exercise protocols of varying intensities. Ten Appalachian State University students experienced in resistance exercise completed three different resistance exercise protocols on different days using a randomized, crossover design, with one week of rest between each protocol. The protocols included 1) hypertrophy: four sets of 10 repetitions in the
squat at 75% of a 1-repetition maximum (1RM) (90-second rest periods); 2) strength: 11 sets of 3 repetitions at 90% 1RM (5-minute rest periods); and 3) power: eight sets of six repetitions of jump squats at 0% 1RM (3-minute rest periods). The volume of resistance exercise completed during each protocol was determined with four different methods: 1) volume load (VL) (repetitions [no.] × external load [kg]); 2) maximum dynamic strength volume load (MDSVL) (repetitions [no.] × [body mass - shank mass (kg) + external load (kg)]); 3) time under tension (TUT) (eccentric time + milliseconds) + concentric time + milliseconds)); and 4) total work (TW) (force [N] × displacement [m]). The volumes differed significantly (P < 0.05) between hypertrophy and strength in comparison with the power protocol when VL and MDSVL were used to determine the volume of resistance exercise completed. Furthermore, significant differences in TUT existed between all three resistance exercise protocols. The TW calculated was not significantly different between the three protocols. These data imply that each method examined results in substantially different values when comparing various resistance exercise protocols involving different levels of intensity.

Halil Tasxkin (2009) determined the effect of circuit training directed toward motion and action velocity over the sprint-agility and anaerobic endurance. A total of 32 healthy male physical education students with a mean age of 23.92 ± 1.51 years were
randomly allocated into a circuit training group (CTG; n = 16) and control group (CG; n = 16). A circuit training consisting of 8 stations was applied to the subjects three days a week for 10 weeks. Circuit training program was executed with 75% of maximal motion numbers in each station. The FIFA Medical Assessment and Research Centre (F-MARC) test battery, which was designed by FIFA, was used for measuring sprint-agility and anaerobic endurance. Pre- and post training testing of subjects included assessments of sprint-agility and anaerobic endurance. Following training, there was a significant (p, 0.05) difference in sprint-agility between pre- and post testing for the CTG (pre test = 14.76 ± 0.48 seconds, post test = 14.47 ± 0.43 seconds). Also, there was a significant (p, 0.05) difference in anaerobic endurance between pre- and post testing for the CG (pre test = 31.53 ± 0.48 seconds, posttest = 30.73 ± 0.50 seconds). In conclusion, circuit training, which is designed to be performed three days a week during 10 weeks of training, improves sprint-agility and anaerobic endurance.

*Bevan, et al., (2009)* after a bout of heavy resistance training (HRT), skeletal muscle is in both a fatigued and potentiated state. Subsequent muscle performance depends on the balance between these 2 factors. To date, there is no uniform agreement about the recovery time required between the HRT and subsequent muscle performance to gain performance benefits in the upper body.
The aim of the present study was to determine the recovery time required to observe enhanced upper-body muscle performance after HRT (i.e., complex training). Twenty-six professional rugby players performed a ballistic bench press (BBP) at baseline and at approximately 15 seconds and 4, 8, 12, 16, 20, and 24 minutes after HRT (3 sets of 3 repetitions at 87% 1 repetition maximum). Peak power output (PPO) and throw height were determined for all BBPs. A significant time effect with regard to PPO (F = 29.145, partial Eta2 = 0.538, p < 0.01) and throw height (F = 17.362, partial Eta2 = 0.410, p < 0.01) was observed. Paired comparisons indicated a significant decrease in PPO and throw height in the BBP performed approximately 15 seconds after the HRT compared with the baseline BBP. After 8 minutes of recovery from the HRT, both PPO and throw height were significantly higher than the PPO and throw height recorded at baseline (e.g., PPO: 879 ± 100 vs. 916 ± 116 W, p < 0.01).

It was concluded that muscle performance can be significantly enhanced after bouts of HRT during a BBP providing that adequate recovery (8 min) is given between the HRT and the explosive activity.

Yetter, Mike and Moir, Gavin (2008) investigated the effects of performing heavy back squats (HBS) and heavy front squats (HFS) on the average speed during each 10-m interval of 40-m sprint trials. In a randomized, crossover design, 10 strength-trained men performed a HBS, HFS or control treatment before performing three
40-m sprint trials separated by three minutes. The HBS and HFS treatments consisted of performing parallel back or front squats with 30%, 50%, and 70% of the subject's one repetition maximum after five minutes of cycling. The control treatment consisted of cycling for five minutes. The sprint trials were performed four minutes after completing the HBS, HFS or control treatments. Significant increases in speed were found during the 10- to 20-m interval for the HBS compared with the control treatment (mean difference, 0.12 m·s⁻¹; 95% likely range, 0.05-0.18 m·s⁻¹; P = 0.001). During the 30- to 40-m interval, HBS produced significantly greater speeds compared with the HFS treatment (mean difference, 0.24 m·s⁻¹; 95% likely range, 0.02-0.45 m·s⁻¹; P = 0.034) and the control treatment (mean difference, 0.18 m·s⁻¹; 95% likely range, 0.03-0.32 m·s⁻¹; P = 0.021). The differing effects of the treatments may reflect different levels of muscular activation or different mechanical aspects of the squat exercises. Similarly, the multidimensional nature of sprint running means that other specific exercises may confer improvements in sprinting performance during other intervals. It is suggested that coaches could incorporate HBS into the warm-up procedure of athletes to improve sprinting performance.

*Thierry Paillard (2008)* examined the effects of different types of neuromuscular electrical stimulation (NMES) programs on vertical jump performance. Twenty seven healthy trained male
students in sports-sciences were recruited and randomized into three groups. The control group (C group, n = 8) did not perform NMES training. Two other groups underwent three training sessions a week over 5 weeks on the quadriceps femoris muscle [F group (n = 9): stimulation with an 80 Hz current for 15 min for improving muscle strength; E group (n = 10): stimulation with a 25 Hz current for 60 min. for improving muscle endurance]. The height of the vertical jump was measured before NMES training (test 1), one week (test 2) and five weeks (test 3) after the end of the programs. The results showed that the height of the vertical jump significantly increased in both the F and E groups between tests one and two (five cm and three cm respectively). Results of test 3 showed that both groups preserved their gains. A NMES training program destined to improve muscle endurance does not interfere on vertical jump performance. It can even durably enhance it in the same way as a NMES training program destined to improve muscle strength. Thus, to improve muscle endurance without deteriorating muscle power, sportsmen can use electrical stimulation.

Navarro, et al., (2002) examined the acute effects of heavy-load resistance exercises, static stretching exercises, and heavy load plus static stretching exercises by untrained subjects, and to determine whether these types of exercise have an effect on the performance of squat jumps (SJs) and countermovement jumps
(CMJs). Twenty-four men volunteered to participate in this study and were divided into three groups: 1 group performed the strength exercises using heavy loads (three sets of four repetitions at 90% of each subject’s one-repetition maximum (1RM), a second group performed the heavy-load resistance plus stretching exercises (three sets of four repetitions at 90% of each subject’s 1RM and three stretching exercises for 15 seconds each), and a third group performed the static stretching exercises only (three stretching exercises for 15 seconds each). No significant differences between the groups were seen in vertical jump height, but there were significant differences ($p < 0.004$) in the mean jump height between sets within the training session without taking the treatment type (group) into consideration. Significant differences ($p < 0.001$) were seen in the vertical ground-reaction force in CMJs between sets and training in each group, whereas no differences between groups were seen in SJ; nevertheless, there was a tendency toward significant differences between sets ($p < 0.09$) without considering the treatment type. The data from this study suggest that strength exercises using heavy loads and heavy-load plus stretching exercises did not have a significant effect on the maximal jump height in untrained subjects. Only stretching exercises showed an increase in SJs and CMJs, but these results were not significantly different from all other scores.
Jeffrey, et al. (2001) examined four different methods of calculating volume when comparing resistance exercise protocols of varying intensities. Ten Appalachian State University students experienced in resistance exercise completed three different resistance exercise protocols on different days using a randomized, crossover design, with one week of rest between each protocol. The protocols included 1) hypertrophy: four sets of 10 repetitions in the squat at 75% of a 1-repetition maximum (1RM) (90-second rest periods); 2) strength: 11 sets of three repetitions at 90% 1RM (5-minute rest periods); and 3) power: eight sets of six repetitions of jump squats at 0% 1RM (3-minute rest periods). The volume of resistance exercise completed during each protocol was determined with four different methods: 1) volume load (VL) (repetitions [no.] three external load [kg]); 2) maximum dynamic strength volume load (MDSVL) (repetitions [no.] 3 [body mass two shank mass (kg) + external load (kg)]); 3) time under tension (TUT) (eccentric time +milliseconds] + concentric time +milliseconds)); and 4) total work (TW) (force [N] three displacement [m]). The volumes differed significantly (p, 0.05) between hypertrophy and strength in comparison with the power protocol when VL and MDSVL were used to determine the
volume of resistance exercise completed. Furthermore, significant differences in TUT existed between all three resistance exercise protocols. The TW calculated was not significantly different among the 3 protocols. These data imply that each method examined results in substantially different values when comparing various resistance exercise protocols involving different levels of intensity.

Young, Warren Mcdowell, Mark, Scarlett and Bentley J (2001) determined if straight sprint training transferred to agility performance tests that involved various change-of-direction complexities and if agility training transferred to straight sprinting speed. Thirty-six males were tested on a 30-m straight sprint and six agility tests with 2-5 changes of direction at various angles. The subjects participated in two training sessions per week for six weeks using 20-40-m straight sprints (speed) or 20-40-m change-of-direction sprints (3-5 changes of 100[degrees]) (agility). After the training period, the subjects were retested, and the speed training resulted in significant improvements (p < 0.05) in straight sprinting speed but limited gains in the agility tests. Generally the more complex the agility task, less the transfer from the speed training to the agility task. Conversely, the agility training resulted in significant improvements in the change-of-direction tests (p < 0.05) but no significant improvement (p > 0.05) in straight sprint performance. It
is concluded that straight speed and agility training methods are specific and produce limited transfer to the other. These findings have implications for the design of speed and agility training and testing protocols.

**Lamont, et. al., (2009)** compared the effects of a 6-week, periodized squat training program with (SQTV) or without (SQT) whole-body low-frequency vibration (WBLFV) on acute improvements in jump height and power output over 3 separate testing occasions. Subjects ranged in age from 18 to 30 years and were randomized into 1 of 3 groups (CG, or control group, \( n = 6 \); SQTV, \( n = 13 \); or SQT, \( n = 11 \)). SQTV and SQT performed Smith machine back squat training twice per week with 3 to 5 sets of 55–90% of the 1-repetition maximum (1RM). The SQTV group also received WBLFV (50 Hz; 2-6-mm amplitude) during the 6-week training period before training (30 seconds, 2-4-mm amplitude) and between sets (3 bouts lasting 10 seconds each). Two 30-cm depth jumps and two 20-kg squat jumps were performed after an acute vibration protocol during weeks 1, 3, and 7. Jump height (cm), peak power (Pmax), peak power per kilogram of body mass (Pmax/kg), and mean power (Pav) were recorded for the depth and squat jumps. Although there were no group by trial interactions, percent change in Pmax for the squat jump was greater (\( P < 0.01 \)) for the SQTV group than for the SQT group post WBLFV. In addition, the percent change scores for jump
height and Pmax/kg for the depth jump were greater (P < 0.05) for SQTV than for SQT following WBLFV exposure. WBLFV during the 6-week squat training program resulted in greater acute improvements in power output and jump height for both jump conditions compared to SQT alone.

According to Saez Saez, et al., (2009) 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.

*Sotiropoulos, Travlos, Souglis and Grezios (2009)* compared the changes in body fat percentage and aerobic capacity in professional soccer players, after the implementation of a specific 4-week training regimen during the transition period. Fifty-eight professional soccer players of the Greek Premier National Division were separated in experimental \( n = 38 \) and control groups \( n = 20 \). Body composition and maximum oxygen intake were evaluated before and after a 4-week training regimen followed during the transition period. The experimental design used for analyzing weight (kg), percent body fat (%) and \( VO_2 \) max values \( (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) \) was a \( 2 \times 2 \) \((\text{Groups} \times \text{Measures})\), with Groups as a between-subjects factor and Measures as a within-subjects factor. The level of significance was set at \( P \leq 0.05 \) for all analyses. Analyses of variances showed that the experimental and the control groups achieved statistically significant (a) increases from pre test to post test measures in body weight
(0.595 kg and 1.425 kg, respectively) and percent body fat (0.25 and 0.82, respectively), and (b) decreases in VO₂max values from pre test to post test measures (0.81 and 3.56, respectively). The findings of the study revealed that the players who followed the training regimen compared with the players who did not follow any specific training program gained less weight and body fat and exhibited lower reduction in their VO₂ max values.

**Oliver and Ro Di Brezzo (2009)** examined the effects of functional balance training implemented in addition to regular season practice, competition and strength and conditioning training for collegiate women athletes. Twenty-six members of National Collegiate Athletic Association (NCAA) Division I collegiate women’s volleyball and soccer teams volunteered. A pre-test, post-test group design was used for the study. Pre- and posttest measures were the following: Skindex, body mass index (BMI), single-leg squat, prone quadra-ped core test, Biodex balance test, and a 1-minute sit-up test. The intervention consisted of 10 minutes of Indo Board (a dynamic balance board) training 4 days a week throughout the entire season. The volleyball team served as the intervention group, whereas the soccer team had no intervention. A dependent t-test demonstrated a statistically significant (P < 0.05) improvement on the single-leg squat and 1-minute sit-up test for the volleyball team, whereas the soccer team (no intervention) demonstrated a statistically significant
(P < 0.05) improvement on the 1-minute sit-up test. It was concluded that by training on an unstable surface, the individual is conditioning the core while simultaneously performing balance activities. It was also noted that, although improvements were seen, each subject (both volleyball and soccer) was also active in regular season practice, competition, and strength and conditioning training over the course of the season. Functional balance activities are cost effective and should be added to any form of strength and conditioning program in an attempt to enhance program effectiveness and to develop functional postural activation. Functional postural activation will not only assist with functional performance but also in the prevention of injury.

Gonzalez-Rave, Machado, Navarro-Valdivielso and Vilas-Boas (2009) examined the acute effects of heavy-load resistance exercises, static stretching exercises, and heavy-load plus static stretching exercises by untrained subjects, and to determine whether these types of exercise have an effect on the performance of squat jumps (SJs) and countermovement jumps (CMJs). Twenty-four men volunteered to participate in this study and were divided into 3 groups: 1 group performed the strength exercises using heavy loads (3 sets of 4 repetitions at 90% of each subject’s 1-repetition maximum (1RM), a second group performed the heavy-load resistance plus stretching exercises (3 sets of 4 repetitions at 90% of each subject’s...
1RM and 3 stretching exercises for 15 seconds each), and a third group performed the static stretching exercises only (3 stretching exercises for 15 seconds each). No significant differences between the groups were seen in vertical jump height, but there were significant differences \((P < 0.004)\) in the mean jump height between sets within the training session without taking the treatment type (group) into consideration. Significant differences \((P < 0.001)\) were seen in the vertical ground-reaction force in CMJs between sets and training in each group, whereas no differences between groups were seen in SJ; nevertheless, there was a tendency toward significant differences between sets \((P < 0.09)\) without considering the treatment type. The data from this study suggest that strength exercises using heavy loads and heavy-load plus stretching exercises did not have a significant effect on the maximal jump height in untrained subjects. Only stretching exercises showed an increase in SJs and CMJs, but these results were not significantly different from all other scores.

**Markovic, Simek and Bradic (2008)** examined the acute effects of upper-body maximal dynamic contractions on maximal throwing speed with 0.55- and 4-kg medicine balls. It was hypothesized that heavy preloading would transiently improve throwing performance only when overcoming the heavier of the two loads. Twenty-three male volunteers were randomly allocated into experimental \((n = 11)\) and control \((n = 12)\) groups. Both groups
performed initial and final seated medicine ball throws from the chest, and the maximal medicine ball speed was measured by means of a radar gun. Between the two measurements, the control group rested passively for 15 minutes, and the experimental group performed three sets of three-repetition maximum bench presses. For the 0.55-kg load, a $2 \times 2$ repeated-measures analysis of variance revealed no significant effect of time $\times$ group interaction ($P = 0.22$), as well as no significant time ($P = 0.22$) or group ($P = 0.72$) effects. In contrast, for the 4-kg load, a significant time $\times$ group interaction ($P = 0.004$) and a significant time ($P = 0.035$) but not group ($P = 0.77$) effect were observed. Analysis of simple main effects revealed that the experimental group significantly (8.3%; $P < 0.01$) improved maximal throwing speed with the 4-kg load. These results support our research hypothesis and suggest that the acute effects of heavy preloading on upper-body ballistic performance might be load specific. In a practical sense, the findings suggest that the use of upper-body heavy resistance exercise before ballistic throwing movements against moderate external loads might be an efficient training strategy for improving an athlete's upper-body explosive performance.

\textit{Salonikidis, et al., (2008)} Reaction time, first-step quickness, lateral (side steps), and forward speed over short distances are important parameters for tennis performance. The aims of this
study were: (i) to diagnose the presence of laterality in tennis lateral movements and (ii) to compare the effects of plyometric training (PT), tennis-specific drills training (TDT), and combined training (CT) on performance in tennis-specific movements and power/strength of lower limbs. Sixty-four novice tennis players (21.1 ± 1.3 years) were equally (n = 16) assigned to a control (C), PT, TDT, or CT. Training was performed 3 times/week for 9 weeks. Testing was conducted before and after training for the evaluation of reaction time (single lateral step), 4-m lateral and forward sprints, 12-m forward sprints with and without turn, reactive ability, power and strength. There was a significant difference in lateral speed (side-steps) between the 2 sides (P < 0.05). PT, TDT, or CT improved the 4m lateral and forward sprints (P < 0.05). PT and CT improved also the reaction time of the slow side (P < 0.05), whereas TDT and CT improved the 12-m sprint performances with and without turn (P < 0.05). Power and strength improved in most tests after PT and CT. Lateral and forward sprints were correlated (r = -0.50 to -0.75; P < 0.05) with power/strength. In conclusion, PT improved fitness characteristics that rely more on reactive strength and powerful push-off of legs such as, lateral reaction time, 4-m lateral and forward sprints, drop jump and maximal force. TDT improved all 4-m and 12-m sprint performances, whereas CT appeared to incorporate the advantage of both programs and improved most tests items. Tennis coaches should be aware that
each training regimen may induce more favorable changes to different aspects of fitness.

**Santos, et al., (2008)** examined the effects of a complex training program, a combined practice of weight training and plyometrics, on explosive strength development of young basketball players. Twenty-five young male athletes, aged 14-15 years old, were assessed using squat jump (SJ), countermovement jump (CMJ), Abalakov test (ABA), depth jump (DJ), mechanical power (MP), and medicine ball throw (MBT), before and after a 10-week in-season training program. Both the control group (CG; n = 10) and the experimental group (EG; n = 15) kept up their regular sports practice; additionally, the EG performed 2 sessions per week of a complex training program. The EG significantly improved in the SJ, CMJ, ABA, and MBT values (P < 0.05). The CG significantly decreased the values (P < 0.05) of CMJ, ABA, and MP, while significantly increasing the MBT values (P < 0.05). The results support the use of complex training to improve the upper and lower body explosively levels in young basketball players. In conclusion, this study showed that more strength conditioning is needed during the sport practice season. Furthermore, It is also concluded that complex training is a useful working tool for coaches, innovative in this strength-training domain, equally contributing to a better time-efficient training.
Caruso, et al., (2008) examined the effects of resistance exercise (REX) mode on jump performance, subjects were assigned to one of three groups over a 6-week period with no cross-over. Subjects were assigned to leg and calf press REX on either a standard (n = 10) or ergometer (n = 9) device while a third group (n = 9) served as controls (CTRL). REX subjects worked out twice per week, which consisted of a three-set, 10-repetition paradigm for leg and calf press exercises. Immediately before and after the 6-week period, subjects performed tests that assessed jump (standing vertical jump, four-jump test protocol, depth jump) ability, while a fourth estimated knee extensor fast-twitch percentage (FT%) from fatigue incurred through a 50-repetition isokinetic protocol. Data analyses utilized 3 × 2 (group × time) repeated-measures ANCOVAs. Several dependent variables showed effects by group (standard REX, ergometer REX > CTRL) and time (post > pre). An interaction occurred for explosive leg power factor, a four-jump test variable, with standard REX post-test values as the interaction source. A trend for an interaction occurred for depth jump hang time, as ergometer REX values improved over time. Results suggest that mode-specific adaptations occur with REX training. Thus, athletes are best served with the selection of a REX device that is most specific to the demands of their jump performance task.
Stanganelli, et al., (2008) the under-19 Brazilian volleyball national team has achieved great performances at international competitions. Because the vertical jump capacity is critical for success in volleyball, the purpose of this study was to identify the training-induced adaptations on jump capacity assessed by general and specific tests during 3 different moments (i.e., T1, T2, and T3) of a macrocycle of preparation for the world championship. The sample was composed of 11 athletes from the Brazilian national team-World Champion (age, 18.0 ± 0.5 years; height: 198.7 ± 5.4 cm; and body mass, 87.3 ± 5.9 kg). They were evaluated for jumping capacity by the following tests: squat jump (SJ), countermovement jump (CMJ), and jump anaerobic resistance (15 seconds) (JAR) and standing reach, height, and vertical jump tests for attack and block. Descriptive statistics were computed, and a repeated-measures analysis of variance was used. The Tukey-Kramer post hoc test was used when appropriate. Significance was set at $P \leq 0.05$. The results showed that the training-induced adaptations on the SJ (3.9%) and CMJ (2.3%) were not statistically significant. The JAR showed statistical significance between T2 and T3 (9.6%), while the attack height and block height presented significant differences between T1 and T2 (2.5% and 3.3%, respectively) and T1 and T3 (3.0% and 3.5%, respectively). The volume of training was quantified between weeks 1 and 9 (10,750 minutes, 1,194 ± 322 min·wk⁻¹) and between weeks 10
and 18 (8,722 minutes, 969 ± 329 min·wk⁻¹). In conclusion, this study showed that there were progressive and significant training-induced adaptations, mainly on the tests that simulated the specific skills, such as spike and block, with the best results being reached after the first 9 weeks of training. This probably reflected not only the individual’s capacity to adapt, but also the characteristics of the training loads prescribed during the entire macrocycle.

Mihalik, et al., (2008) compared whether there were differences in vertical jump height and lower body power production gains between complex and compound training programs. A secondary purpose was to determine whether differences in gains were observed at a faster rate between complex and compound training programs. Thirty-one college-aged club volleyball players (11 men and 20 women) were assigned into either a complex training group or a compound training group based on gender and pre-training performance measures. Both groups trained twice per week for 4 weeks. Work was equated between the 2 groups. Complex training alternated between resistance and plyometric exercises on each training day; whereas, compound training consisted of resistance training on one day and plyometric training on the other. Our analyses showed significant improvements in vertical jump height in both training groups after only 3 weeks of training (P < 0.0001); vertical jump height increased by approximately 5% and
9% in the complex and compound training groups respectively. However, neither group improved significantly better than the other, nor did either group experience faster gains in vertical leap or power output. The results of this study suggest that performing a minimum of 3 weeks of either complex or compound training is effective for improving vertical jump height and power output; thus, coaches should choose the program which best suits their training schedules.

According to Daniel, Alvar and Brent (2007) complex training is the simultaneous combination of heavy resistance training and plyometrics. The objective of this study was to test the effects of complex training vs. heavy resistance or plyometric interventions alone on various power-specific performance measures. Forty-five male division II junior college baseball players participated in 3 separate 4-week resistance training interventions. Subjects were randomly assigned to one of three groups. In a counterbalanced rotation design, each group participated in complex, heavy resistance and plyometric training interventions. Each individual was tested in 20-yd (SP20), 40-yd (SP40), 60-yd (SP60), vertical jump, standing broad jump, and T-agility measures pre- and post-4-week training interventions. There was no statistical significant difference (p = 0.11) between groups across all performance measures. Review of each distinct training intervention revealed greater percent improvements in SP20 (0.55; -0.49; -0.12), SP40 (0.26; -0.72; -1.33), SP60 (0.27;
standing broad jump (1.80; 0.67; 1.1), and T-agility (2.33; 1.23; -0.04) with complex training interventions than with the heavy resistance or plyometric training interventions respectively. Plyometric only training showed greater percent changes in vertical jump (1.90) than with complex (0.97) or heavy resistance training (0.36). The present results indicate that complex training can provide strength and conditioning professional’s equal, if not slightly greater, improvements in muscular power than traditional heavy resistance and plyometric only interventions in moderately trained athletes. Complex training can be another valuable method for short-term power and speed improvements in athletes in isolation or in conjunction with other power development methods.

Comyns, Harrison and Jensen (2005) compared if a heavy resistive exercise cause performance enhancement of a slow stretch–shortening cycle exercise and if there is an optimal rest interval. Eighteen subjects performed countermovement jumps (CMJs) before and after a 5 repetition maximum back squat lifting protocol. This procedure was repeated 4 times over 2 days using rest intervals of 30 seconds and 2, 4, and 6 minutes. Flight time and peak ground reaction forces (GRF) were the dependent variables. All jumps were performed on a specially constructed sledge and force platform apparatus. Repeated measures analysis of variance found a significant reduction in flight time at the 30-second and 6-minute
interval (p 0.05). No significant difference was found between men and women. Only the men showed an enhancement in jump performance after the 4-minute interval. The improvement window was different for each subject, and an analysis of the greatest increase and decrease in flight time and peak GRF was conducted, showing a significant decrease for men and women and a significant increase in flight time for men and peak ground reaction force for women. The results suggest that complex training can benefit or inhibit CMJ performance depending on the rest interval. The individual determination of the intra-complex rest interval may be necessary in the practical setting.

**Fletcher, Hartwell and Matthew (2004)** examined the effect of a combined weights and plyometrics program 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 > 0.05) changes, while 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
Randall I. Jensen and William P. Ebben (2003) In this study the investigators attempt to determine if there is an ergogenic advantage associated with complex training and if there is an optimal time for performing plyometrics after the strength training set. Subjects were 21 NCAA Division I athletes who performed a countermovement vertical jump, a set of 5 repetitions maximum (5RM) squats, and 5 trials of countermovement vertical jump at intervals of 10 seconds and 1, 2, 3, and 4 minutes after the squat. Jump height and peak ground reaction forces were acquired via a force platform. The pre-squat jump performance was compared with the post-squat jumps. Repeated measures ANOVA determined a difference (p # 0.05) between genders and that jump performance immediately following the squat exercise was hindered (0.66 m), but no effect (p . 0.05) was found comparing subsequent jumps (0.72–0.76 m) to the re-squat condition (0.74 m). When comparing high to low strength individuals, there was no effect on jump performance following the squat (p. 0.05). In conclusion, complex training does not appear to enhance jumping performance significantly and actually decreases it when the jump is performed immediately following the strength training set; however, a non-significant trend toward improvement seemed to be present. Therefore to optimize jump
performance it appears that athletes should not perform jumps immediately following resistance training. It may be possible that beyond 4 minutes of recovery performance could be enhanced; however, that was not within the scope of the current study.

*Duthie, Young, and Aitken (2002)* examined power performance in jump squats when using the complex and contrast training methods. Eleven (*n* = 11) women participated in a familiarization session and in three randomly ordered testing sessions. One session involved completing sets of power exercises (jump squats) before sets of half squats (traditional method). The second session involved sets of half squats before sets of jump squats (complex method). A third session involved the alternation of sets of half squats and jump squats (contrast method). No significant difference in jump squat performance between each of the training methods as found. There was a significant difference (*p* < 0.05) in the first set of each session, with the complex method having a significantly lower peak power. Further, there was a significant difference (*p* < 0.05) in performance changes between the higher and lower strength groups, with the higher strength group having a greater improvement in performance using the contrast training method compared with the traditional method. It was concluded that contrast training is advantageous for increasing power output but only for athletes with relatively high strength levels.