Capitalizing on the reviews of expert researchers can be fruitful in providing helpful ideas and suggestions keeping this in mind the research scholar made an attempt to go through the related literatures available in the libraries of University College of Physical Education, Acharya Nagarjuna University, Guntur (Dist), Andhra Pradesh. I have scanned the literature and research work, published so far here and abroad, on the allied field and physical education and sports. Extensive studies regarding strength and plyometric training impact on body composition and physical fitness variables of kabaddi players. The relative studies found from various sources are cited below.

**Strength training**

**Studies pertaining to body composition**

Rahimi, (2006) stated that the optimal weight training intensity to improve body composition in overweight men is unclear. The purpose of this study was to determine the effect of 12 weeks of high intensity versus moderate intensity weight training of equal work output on body composition in overweight men (BMI = 25-29.9 kg/m²). Twenty sedentary men (age: 27 ± 0.5 year; Body weight: 84 ± 1.43 kg; BMI: 28.23 ± 1.11 kg/m²)
were randomized in two equal groups (n = 10): 1) moderate intensity exercise (MI; 5sets*6reps [60% (1RM-1repetition maximum)]; and 2) high intensity exercise (HI; 5sets*6reps [85% 1RM]). The weight training program was performed 3d.w . Relative body fat (% BF) was assessed by a skin-fold caliper. Significant differences between and within the groups were analyzed using a two-way split-plot analysis of variance (ANOVA). Statistical significance was accepted at p<0.05. The two-way ANOVA showed statistically significant differences between HI and MI groups, therefore, the Scheffe Post-Hoc Test showed that there was a significant decrease (p<0.05) in the relative body fat (BF) (D = 27%), percent of body fat (%BF) (22%), BMI (D = 9.34%), and body weight (BW) (D = 6.51%) in the HI group during the course of the study than in the MI group also, comparison of means between the pre/post test showed statistically significant decreases in skinfold thickness (HI = 45%, p = 0.001; MI = 25%, p = 0.02), percent of body fat (HI = 41%, p = 0.001; MI = 23%, p = 0.04), BMI (HI = 21.5%, p = 0.001; MI = 13.7%, p = 0.03), and body weight (HI = 21.58%, p = 0.001; MI = 13.82%, p = 0.01) after participation in a 12-week weight training program. They concluded that 12 weeks of HI weight training may be more effective in improving body
composition than MI weight training in overweight young men with physical characteristics similar to the ones found in the present study.

Boyer (1990) compared the strength and body composition changes produced by three different strength training programs: isotonic, involving free weights; compound variable resistance, involving Nautilus (P.O. Drawer 809014, Dallas Texas); and linear variable resistance, utilizing the Soloflex (570 NE 53rd, Hillsboro, Oregon) device. Thirty-two female subjects performed pre- and posttests for strength utilizing the one repetition maximum (1 RM) test on three exercises from each of the training programs. Subjects were pre- and posttested on four skinfold thicknesses, percent body fat and body girths. The subjects utilized one of three training programs three times a week for 12 weeks. All three modes of training were found to increase strength levels significantly (p < 0.05). Subjects who trained with free weights or Nautilus performed at significantly higher levels when tested for 1 RM on exercises included in their training program. Strength gains of the nautilus training group were significantly higher levels (p < 0.05) than those of soloflex training group on the free weight leg press 1 RM test. There were no other significant different strength gains as a result of the
training programs. The training programs to produce significant decreases in the arm, thigh and suprailiac skinfolds, as well as decreases in percent body fat. No significant changes were found in the girth measurements or abdominal skin fold. No significant differences were found among the training groups for the effect on body composition variables. They concluded that the three training programs produced comparable changes in body composition and strength, with training specificity in strength gains.

Fleck (1999) stated that variation or periodization of training is an important concept in designing weight-training programs. To date, the majority of studies examining periodization of weight training have used a traditional strength/power training model of decreasing training volume and increasing training intensity as the program progresses. The majority of these studies have used males as subjects and do support the contention that periodized programs can result in greater changes in strength, motor performance, total body weight, lean body mass, and percent body fat than nonperiodized programs. However, studies are needed examining why periodized training is more beneficial than nonperiodized training. Studies are also needed to examine the response of
females, children, and seniors to periodized weight-training programs and the response to periodized models other than the traditional strength/power training model.

Ramírez-Campillo et al. (2013) examined the effects of a localized muscle endurance resistance training program on total body and regional tissue composition. Seven men and 4 women (aged 23 ± 1 years) were trained with their nondominant leg during 12 weeks, 3 sessions per week. Each session consisted of 1 set of 960–1,200 repetitions (leg press exercise), at 10–30% 1 repetition maximum. Before and after training, body mass, bone mass, bone mineral density (BMD), lean mass, fat mass, and fat percentage were determined by dual-emission x-ray absorptiometry. Energy intakes were registered using a food recall questionnaire. On the whole-body level, body mass, bone mass, BMD, lean mass, or body fat percentage were not significantly changed. However, body fat mass significantly decreased by 5.1% (pre exercise: 13.5 ± 6.3 kg; post exercise: 12.8 ± 5.4 kg, p < 0.05). No significant changes in bone mass, lean mass, fat mass, or fat percentage were observed in both the control and trained leg. A significant (p < 0.05) decrease in fat mass was observed in the upper extremities and trunk (10.2 and 6.9%, respectively, p < 0.05). The reduction of fat mass in the
upper extremities and trunk was significantly greater ($p < 0.05$) than the fat mass change observed in the trained leg but not in the control leg. No significant changes were observed in energy intake pre- and postexercise intervention (2,646 ± 444 kcal·d$^{-1}$ and 2,677 ± 617 kcal·d$^{-1}$, respectively). In conclusion, the training program was effective in reducing fat mass, but this reduction was not achieved in the trained body segment. Their results expand the limited knowledge available about the plastic heterogeneity of regional body tissues when a localized resistance training program is applied.

**Dixon and Andreacci (2009)** examined the effect of a resistance exercise bout on percent body fat (%BF) measured by leg-to-leg and segmental bioelectrical impedance analysis (LBIA; SBIA) in adults. Eighty-six volunteers (45 women; 41 men) reported to the weight training facility on 2 separate occasions. After an initial LBIA and SBIA assessment, subjects performed 60 minutes of continuous resistance exercise, or did nothing, which served as the control. During the resistance exercise trial, subjects completed an 8-exercise circuit protocol consisting of 3 sets of 10 to 12 repetitions at 65-75% of 1 repetition maximum for each exercise. Subjects were provided with a bottle of water for consumption during both trials. Body composition was
reassessed 60 minutes after baseline for comparison. For the resistance exercise trial, significant reductions (p < 0.05) in SBIA-measured %BF (women = 0.9 ± 1.0%; men = 1.4 ± 0.8%) and impedance (women = 22.2 ± 17.0 Ω; men = 22.3 ± 10.0 Ω) were observed, whereas LBIA body composition measurements remained unchanged. After the control trial, significant increases (p < 0.05) in SBIA-measured %BF (women = 0.6 ± 0.8%; men = 0.5 ± 0.7%) and impedance (women = 7.8 ± 12.6 Ω; men = 4.7 ± 8.3 Ω) and LBIA-measured %BF (women = 0.4 ± 0.7%; men = 0.4 ± 0.5%) were observed because of the body mass gain (approximately 300-400 g) after drinking. When using SBIA, assessments should be performed before resistance exercise to eliminate exercise-induced alterations in %BF. Conversely, resistance exercise had no effect on the LBIA measurements, and, therefore, following pretest exercise guidelines may not be necessary when this technology is used for the body composition assessment.

**Groves and Gayle (1993)** evaluated the possible benefits of year-round strength training for male intercollegiate basketball players. Eight players were evaluated four times (T1-T4) during a 12-month period. Test items included body weight, body composition, the Margaria-Kalamen Stair Test, vertical
jump, and 1-RM bench press. The repeated-measures ANOVA technique was used to test for significant differences across test scores. Percent body fat consistently decreased over time (p<.05), while body weight decreased (p<.05) from T1 to T2 and then gradually returned to the T1 level by T4. This shift toward a higher percent lean body mass might explain a 27.5-lb mean 1-RM bench press gain over the same time period. Correlational analyses indicated that the positive relationship of weight to strength decreased from r = 0.33 to r = 0.04, indicating that size is less of a predictor of strength when strength training supplements traditional basketball training. Vertical jump and stair test mean scores did not change significantly. Results suggest there are physical and physiological benefits associated with year-round strength training for male intercollegiate basketball players, although control data were not available.

Sotiropoulos et al. (2009) evaluated 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 (ml·kg$^{-1}$·min$^{-1}$) was a $2 \times 2$ (Groups × 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 pretest to posttest 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 VO$_2$ max values from pretest to posttest measures (0.81 and 3.56, respectively). Their findings revealed that the players who followed the training regimen compared with the players that did not follow any specific training program gained less weight and body fat and exhibited lower reduction in their VO$_2$ max values.

**Velez, Golem and Arent (2010)** examined the effects of a structured resistance training program on strength, body composition, and self-concept in normal and overweight Hispanic adolescents. Male and female participants ($n = 28$; 16.1 ± 0.2 y; 164.5 ± 1.4 cm; 63.3 ± 2.5 kg; 20.0 ± 1.7% body fat [BF]) were recruited from a predominantly Hispanic high school. Prior
to the 12-week program, strength, body composition, and self-concept were assessed. Subjects were randomly assigned to a control group (CON; n = 15) or to a resistance training group (RT; n = 13) that participated in supervised strength training 3 days/week. All measures were repeated at the end of the 12-week program. RT had significantly greater strength increases for bench press (p < 0.001), seated row (p = 0.002), shoulder press (p < 0.001), and squats (p = 0.002). RT had significant reductions in %BF (p = 0.001), whereas CON had slightly increased %BF. RT had an increase in condition/stamina competence (p = 0.008), attractive body adequacy (p = 0.017), and global self-worth (p = 0.013) from pretest to posttest, whereas no change was observed for CON. In conclusion, resistance training resulted in significant physiological and psychological improvements in Hispanic adolescents compared to typical school-based activities. Their findings indicate that resistance training can be incorporated into the activities of Hispanic adolescents to promote improved health and fitness.

**Studies pertaining to physical fitness variables**

*Faigenbaum, et al., (2005)* compared early muscular fitness adaptations in children in response to low repetition maximum (LRM) and high repetition maximum (HRM) resistance
training. Twenty-three girls and 20 boys between the ages of 8.0 and 12.3 years (mean age 10.6 ± 1.3 years) volunteered to participate in this study. Children performed one set of 6 to 10 RM (n = 12) or one set of 15 to 20 RM (n = 19) on child-size exercise machines twice weekly over 8 weeks. Children in the control group (n = 12) did not resistance train. Maximum strength (1 RM) on the chest press, local muscular endurance (15 RM) on the leg press, long jump, vertical jump, and v-sit flexibility were assessed at baseline and posttraining. The LRM and HRM groups made significantly greater gains in 1 RM strength (21% and 23%, respectively) as compared with the control group (1%). Only the HRM group made significantly greater gains in 15 RM local muscular endurance (42%) and flexibility (15%) than that recorded in the control group (4% and −5%, respectively). If children perform one set per exercise as part of an introductory resistance training program, these findings favor the prescription of a higher RM training range.

Behm, et al., (2008) review papers have refuted the myths associated with resistance training (RT) in children and adolescents. With proper training methods, RT for children and adolescents can be relatively safe and improve overall health. The objective of this position paper and review is to highlight
research and provide recommendations in aspects of RT that has not been extensively reported in the pediatric literature. In addition to the well-documented increases in muscular strength and endurance, RT has been used to improve function in pediatric patients with cystic fibrosis and cerebral palsy, as well as pediatric burn victims. Increases in children’s muscular strength have been attributed primarily to neurological adaptations due to the disproportionately higher increase in muscle strength than in muscle size. Although most studies using anthropometric measures have not shown significant muscle hypertrophy in children, more sensitive measures such as magnetic resonance imaging and ultrasound have suggested that hypertrophy may occur. There is no minimum age for RT for children. However, the training and instruction must be appropriate for children and adolescents, involving a proper warm-up, cool-down, and appropriate choice of exercises. It is recommended that low- to moderate-intensity resistance exercise should be done 2–3 times/weeks on non-consecutive days, with 1–2 sets initially, progressing to 4 sets of 8–15 repetitions for 8–12 exercises. These exercises can include more advanced movements such as Olympic-style lifting, plyometrics, and balance training, which can enhance strength, power, co-
ordination, and balance. However, specific guidelines for these more advanced techniques need to be established for youth. In conclusion, an RT program that is within a child’s or adolescent’s capacity and involves gradual progression under qualified instruction and supervision with appropriately sized equipment can involve more advanced or intense RT exercises, which can lead to functional (i.e., muscular strength, endurance, power, balance, and co-ordination) and health benefits.

**Weiss, et al., (2010)** stated that functional resistance training becomes a more popular method to improve muscular fitness, questions remain regarding the effectiveness of functional training compared to traditional resistance training. Therefore, the purpose of this study was to determine whether functional training has similar effects as traditional resistance training on muscular strength and endurance, flexibility, agility, balance, and anthropometric measures in young adults. In this study, 38 healthy volunteers, aged 18–32 years, were randomly placed into a control group [traditional (n = 19)] and an experimental group [functional (n = 19)]. The participants were tested prior to and after completing the 7-week training study. The testing battery included: weight, girth measurements, flexibility, agility, lower back flexion and extension endurance,
push-up test, sit-up test, one-leg balance, one-repetition maximum (1-RM) bench press and squat. Results indicated significant (p < 0.05) increases in push-ups, back extension endurance, 1-RM bench press, 1-RM squat, and one-leg balance within each group following training. Traditional training also elicited significant (p < 0.05) increases in bicep girth, forearm girth, calf girth, and sit-ups, while the functional training group experienced significant (p < 0.05) increases in shoulder girth and flexibility. Forearm girth and flexion test time changes following training were the only parameter where there were significant (p < 0.05) differences between training groups. Collectively, their results suggest that both programs are equally beneficial for increasing endurance, balance, and traditional measures of strength. However, changes in various girth measures, torso flexor endurance and flexibility appear to be program-specific.

**Kim et al. (2011)** compared super slow resistance training (SRT) to traditional resistance training (TRT) during early phase adaptations in strength, aerobic capacity, and flexibility in college-aged women. Subjects were randomly assigned to SRT (n = 14); TRT (n = 13); or control (CON; n = 8) groups. To equalize training times, TRT trained 3 times per week for 25 minutes each session, whereas SRT trained twice a week for 35 minutes
each session. Both groups trained for 4 weeks, whereas the CON group maintained normal daily activities. Workouts consisted of 5 exercises: shoulder press, chest press, leg press, low row, and lat pull down. The SRT group completed 1 set of each exercise at 50% 1RM until momentary failure with a 10-second concentric and a 10-second eccentric phase. The TRT group completed 3 sets of 8 repetitions at 80% 1RM for each exercise, with 4 seconds of contraction time for each repetition. Groups were statistically similar at baseline. There was a significant (p ≤ 0.01) time main effect for flexibility with the greatest improvements occurring for the training groups (SRT 14.7% and TRT 11%). All strength tests had significant (p ≤ 0.01) time main effects but no group or group by time interactions. Both training groups had large percent improvements in strength compared to CON, but the large variability associated with the SRT group resulted in only the TRT group being significantly different from the CON group. They concluded that improvements were similar for the TRT and SRT groups, but only the TRT group reached statistical significance for the strength improvements, and both groups were equally effective for improving flexibility.

Santos and Janeira (2008) evaluated 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). Our results support the use of complex training to improve the upper and lower body explosivity levels in young basketball players. They concluded from this study showed that more strength conditioning is needed during the sport practice season. Furthermore, they also conclude that complex training is a useful working tool for coaches, innovative in this strength-training domain, equally contributing to a better time-efficient training.

Turbanski and Schmidtbleicher (2010) stated that strength training in subjects with spinal cord injury (SCI),
especially in athletes performing competitive sports. Sixteen male subjects participated in this study-8 with SCI and 8 healthy physical education students (control subjects). The 8-week program consisted of heavy-resistance exercise performed twice per week with 10 to 12 repetitions in 5 sets. Subjects’ performances were tested in static and in dynamic conditions concerning several strength and power parameters. Furthermore, we tested 10-m sprinting performance in wheelchair athletes. Overall, wheelchair athletes and control subjects achieved similar results; in almost all parameters both groups improved considerably in post-testing. Regarding percentages in most strength and power parameters, wheelchair athletes showed a tendency to benefit more from the strength training performed in the present study. Using analyses of group differences, however, only the comparison of effects on rate of force development ($p = 0.010$) resulted in a significant higher improvement for wheelchair athletes. In contrast to previous assumptions about minor adaptation capacities to training exercises in patients with SCI, their study proved clear effects of strength training. In conclusion, we suggest that heavy resistance training should be of increasing importance in wheelchair sports.
Álvarez et al. (2012) determined the effects of an 18-week strength training program on variables related to low-handicap golfers' performance. Ten right-handed male golfers, reporting a handicap of 5 or less, were randomly divided into two groups: the control group (CG) (N = 5, age: 23.9 ± 6.7 years) and the treatment group (TG) (N = 5, age: 24.2 ± 5.4 years). CG players followed the standard physical conditioning program for golf, which was partially modified for the TG. The TG participated in an 18-week strength training program divided into three parts: maximal strength training including weightlifting exercises (2 days a week for 6 weeks), explosive strength training with combined weights and plyometric exercises (2 days a week for 6 weeks), and golf-specific strength training, including swings with a weighted club and accelerated swings with an acceleration tubing system (3 days a week for 6 weeks). Body mass, body fat, muscle mass, jumping ability, isometric grip strength, maximal strength (RM), ball speed, and golf club mean acceleration were measured on five separate occasions. The TG demonstrated significant increases (p < 0.05) in maximal and explosive strength after 6 weeks of training and in driving performance after 12 weeks. These improvements remained unaltered during the 6-week golf-specific training period and even during a 5-week
detraining period. It may be concluded that an 18-week strength training program can improve maximal and explosive strength and these increases can be transferred to driving performance; however, golfers need time to transfer the gains.

*Santos and Janeira (2012)* assessed the effects of a lower- and upper-body 10-week in-season resistance training program on explosive strength development in young basketball players. Twenty-five adolescent male athletes, aged 14–15 years old, were randomly assigned to an experimental group (EG; n = 15) and a control group (CG; n = 10). The subjects were assessed at baseline and after training for squat jump (SJ), countermovement jump (CMJ), Abalakov test, drop jump, and seated medicine ball throw (MBT). The EG showed significant increases (p < 0.05) in all the variable scores. Conversely, the CG significantly decreased (p < 0.05) in SJ, CMJ, and Abalakov test scores and significantly increased in the results of MBT test (p < 0.05). The groups were similar on pretest, but significant differences (p < 0.05) occurred on posttest in all the variables. Their results showed that a 10-week in-season resistance training program with moderate volume and intensity loads increased vertical jump and MBT performance in adolescent male basketball players. Coaches should know that such a short
resistance training program specifically designed for young basketball players induce increased explosivity levels, which are essential to a better basketball performance, with no extra overload on adolescents' skeletal muscle development.

Ronnestad et al. (2008) compared the effects of combined strength and plyometric training with strength training alone on power-related measurements in professional soccer players. Subjects in the intervention team were randomly divided into 2 groups. Group ST (n = 6) performed heavy strength training twice a week for 7 weeks in addition to 6 to 8 soccer sessions a week. Group ST+P (n = 8) performed a plyometric training program in addition to the same training as the ST group. The control group (n = 7) performed 6 to 8 soccer sessions a week. Pretests and posttests were 1 repetition maximum (1RM) half squat, countermovement jump (CMJ), squat jump (SJ), 4-bounce test (4BT), peak power in half squat with 20 kg, 35 kg, and 50 kg (PP20, PP35, and PP50, respectively), sprint acceleration, peak sprint velocity, and total time on 40-m sprint. There were no significant differences between the ST+P group and ST group. Thus, the groups were pooled into 1 intervention group. The intervention group significantly improved in all measurements except CMJ, while the control group showed significant
improvements only in PP20. There was a significant difference in relative improvement between the intervention group and control group in 1RM half squat, 4BT, and SJ. However, a significant difference between groups was not observed in PP20, PP35, sprint acceleration, peak sprinting velocity, and total time on 40-m sprint. Their results suggest that there are no significant performance-enhancing effects of combining strength and plyometric training in professional soccer players concurrently performing 6 to 8 soccer sessions a week compared to strength training alone. However, heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players.

**Ramos Veliz et al. (2014)** examined the effects of 18 weeks of strength and high-intensity training on key sport performance measures of elite male water polo (WP) players. Twenty-seven players were randomly assigned to 2 groups, control (in-water training only) and strength group, (strength training sessions [twice per week] + in-water training). In-water training was conducted 5 d·wk⁻¹. Twenty-meter maximal sprint swim, maximal dynamic strength 1-repetition maximum (1RM) for upper bench press (BP) and lower full squat (FS) body, countermovement jump (CMJ), and throwing velocity were
measured before and after the training. The training program included upper and lower body strength and high-intensity exercises (BP, FS, military press, pull-ups, CMJ loaded, and abs). Baseline-training results showed no significant differences between the groups in any of the variables tested. No improvement was found in the control group; however, meaningful improvement was found in all variables in the experimental group: CMJ (2.38 cm, 6.9%, effect size [ES] = 0.48), BP (9.06 kg, 10.53%, ES = 0.66), FS (11.06 kg, 14.21%, ES = 0.67), throwing velocity (1.76 km·h⁻¹, 2.76%, ES = 0.25), and 20-m maximal sprint swim (−0.26 seconds, 2.25%, ES = 0.29).

Specific strength and high-intensity training in male WP players for 18 weeks produced a positive effect on performance qualities highly specific to WP. Therefore, they propose modifications to the current training methodology for WP players to include strength and high-intensity training for athlete preparation in this sport.

Wong, Chamari and Wisløff (2010) examined the effects of on-field combined strength and power training (CSPT) on physical performance among U-14 young soccer players. Players were assigned to experimental (EG, n = 28) and control groups (CG, n = 23). Both groups underwent preseason soccer training
for 12 weeks. EG performed CSPT twice a week, which consisted of strength and power exercises that trained the major muscles of the core, upper, and lower body. CSPT significantly (p < 0.05) improved vertical jump height, ball-shooting speed, 10 m and 30 m sprint times, Yo-Yo intermittent endurance run (YYIER), and reduced submaximal running cost (RC). CSPT had moderate effect on vertical jump, ball-shooting, 30 m sprint, and YYIER, small effect on 10 m sprint, RC, and maximal oxygen uptake. YYIER had significant (p < 0.05) correlations with 10 m (r = −0.47) and 30 m (r = −0.43) sprint times, ball-shooting speed (r = 0.51), and vertical jump (r = 0.34). The CSPT can be performed together with soccer training with no concomitant interference on aerobic capacity and with improved explosive performances. In addition, it is suggested that CSPT be performed during the preseason period rather than in-season to avoid insufficient recovery/rest or overtraining.

Hermassi et al. (2010) compared the effect of 2 differing 10-week resistance training programs on the peak power (PP) output, muscle volume, strength, and throwing velocity of the upper limbs in handball players during the competitive season. The subjects were 26 men (age 20.0 ± 0.6 years, body mass 85.0 ± 13.2 kg, height 1.86 ± 0.06 m, and body fat 13.7 ± 2.4%). They
were randomly assigned to 1 of 3 groups: control (C; n = 8), heavy resistance (n = 9), or moderate resistance (MR; n = 9) training, performed twice a week. A force-velocity test on an appropriately modified Monark cycle ergometer determined PP. Muscle volumes were estimated using a standard anthropometric kit. One-repetition maximum (1RM) bench press (1RMBP) and 1RM pull-over (1RMPO) scores assessed arm strength. Handball throwing velocity was measured with (TR) and without run-up (TW). Both training programs enhanced absolute PP relative to controls (p < 0.05), although differences disappeared if PP was expressed per unit of muscle volume. Heavy resistance-enhanced 1RMBP and 1RMPO compared to both MR (p < 0.01 and p < 0.05, respectively) and C (p < 0.001 for both tests). Heavy resistance also increased TR and TW compared to C (p < 0.01 and p < 0.05, respectively). Moderate resistance increased only TR compared to C (p < 0.01). Thus, during the competitive season, the PP, 1RMBP, 1RMPO, and TW of male handball players were increased more by 10 weeks of bench press and pull-over training with suitably adapted heavy loads than with moderate loads. It would seem advantageous to add such resistance exercise before customary technical and tactical handball training sessions.
Jullien et al. (2008) assessed the effects of specific leg strength training (as part of a broader exercise program) on running speed and agility in young professional soccer players. Twenty-six male players (ages 17 to 19 years) were divided into 3 groups. The reference group (Re) performed individual technical work only, the coordination group (Co) performed a circuit designed to promote agility, coordination, and balance control (together with some technical work) and the Squat group (Sq) underwent 3 series of 3 squat repetitions (at 90% of the individual maximum value) and a sprint, before competition of the agility circuit and some technical work. These specific training programs were performed 5 times a week for 3 weeks. Before the experimental session and at the end of each week, all players were assessed using 4 types of tests, (agility, a shuttle test with changes of direction, and 2 sprints over 10 and 7.32 meters, respectively), with completion of time being the only performance parameter recorded. Their results indicate that in the short sprints or shuttle sprint with changes in direction, lower limb strengthening did not improve performance. Performance improved in all 3 groups in the agility test but more so in the reference and coordination groups. It appears that soccer-specific training composed of exercise circuits specifically
adapted to the different types of effort actually used in match play can enhance agility and coordination.

Yarrow et al. (2008) evaluated the early-phase muscular performance adaptations to 5 weeks of traditional (TRAD) and eccentric-enhanced (ECC+) progressive resistance training and to compare the acute postexercise total testosterone (TT), bioavailable testosterone (BT), growth hormone (GH), and lactate responses in TRAD- and ECC+-trained individuals. Twenty-two previously untrained men (22.1 ± 0.8 years) completed 1 familiarization and 2 baseline bouts, 15 exercise bouts (i.e., 3 times per week for 5 weeks), and 2 postintervention testing bouts. Anthropometric and 1 repetition maximum (1RM) measurements (i.e., bench press and squat) were assessed during both baseline and postintervention testing. Following baseline testing, participants were randomized into TRAD (4 sets of 6 repetitions at 52.5% 1RM) or ECC+ (3 sets of 6 repetitions at 40% 1RM concentric and 100% 1RM eccentric) groups and completed the 5-week progressive resistance training protocols. During the final exercise bout, blood samples acquired at rest and following exercise were assessed for serum TT, BT, GH, and blood lactate. Both groups experienced similar increases in bench press (approximately 10%) and squat (approximately 22%)
strength during the exercise intervention. At the conclusion of training, postexercise TT and BT concentrations increased (approximately 13% and 21%, respectively, p < 0.05) and GH concentrations increased (approximately 750-1200%, p < 0.05) acutely following exercise in both protocols. Postexercise lactate accumulation was similar between the TRAD (5.4 ± 0.4) and ECC+ (5.6 ± 0.4) groups; however, the ECC+ group's lactate concentrations were significantly lower than those of the TRAD group 30 to 60 minutes into recovery. They concluded that TRAD training and ECC+ training appear to result in similar muscular strength adaptations and neuroendocrine responses, while post exercise lactate clearance is enhanced following ECC+ training.

**Naclerio et al. (2013)** compared the effects of 3 different volume of resistance training (RT) on maximum strength and average power in college team sport athletes with no previous RT experience. Thirty-two subjects (20 men and 12 women, age = 23.1 ± 1.57 years) were randomly divided into 4 groups: low volume (LV; n = 8), 1 set per exercise and 3 sets per muscle group; moderate volume (MV; n = 8), 2 sets per exercise and 6 sets per muscle group; high volume (HV; n = 8), 3 sets per exercise and 9 sets per muscle group; and a non-RT control group (n = 8). The 3 intervention groups were trained for 6 weeks
thrice weekly after a nonperiodized RT program differentiated only by the volume. Before (T1) and after training (T2), 1 repetition maximum (1RM) and maximal average power (AP) produced on the bench press (BP), upright row (UR), and squat (SQ) were assessed by progressive resistance tests. One repetition maximum-BP and 1RM-UR increased significantly in the 3 interventions groups (p < 0.05), whereas only the HV group significantly improved 1RM-SQ (p < 0.01). The MV and HV groups increased AP-BP (p < 0.05), whereas only the LV group improved AP-SQ (p < 0.01). Moderate effect sizes (ES; >0.20 < 0.60) were observed for the 1RM-BP and 1RM-UR in the 3 training groups. High-volume group showed the larger ES for 1RM-BP (0.45), 1RM-UR (0.60), and 1RM-SQ (0.47), whereas the LV produced the higher ES for SQ-AP (0.53). During the initial adaptation period, a HV RT program seems to be a better strategy for improving strength, whereas during the season, an LV RT could be a reasonable option for maintaining strength and enhancing lower-body AP in team sport athletes.

Tanimoto et al. (2008) stated that their previous study showed that relatively low-intensity (~50% one-repetition maximum [1RM]) resistance training (knee extension) with slow movement and tonic force generation (LST) caused as significant
an increase in muscular size and strength as high-intensity (~80% 1RM) resistance training with normal speed (HN). However, that study examined only local effects of one type of exercise (knee extension) on knee extensor muscles. The present study was performed to examine whether a whole-body LST resistance training regimen is as effective on muscular hypertrophy and strength gain as HN resistance training. Thirty-six healthy young men without experience of regular resistance training were assigned into three groups (each n = 12) and performed whole-body resistance training regimens comprising five types of exercise (vertical squat, chest press, latissimus dorsi pull-down, abdominal bend, and back extension: three sets each) with LST (~55-60% 1RM, 3 seconds for eccentric and concentric actions, and no relaxing phase); HN (~80-90% 1RM, 1 second for concentric and eccentric actions, 1 second for relaxing); and a sedentary control group (CON). The mean repetition maximum was eight-repetition maximum in LST and HN. The training session was performed twice a week for 13 weeks. The LST training caused significant (p < 0.05) increases in whole-body muscle thickness (6.8 ± 3.4% in a sum of six sites) and 1RM strength (33.0 ± 8.8% in a sum of five exercises) comparable with those induced by HN training (9.1 ± 4.2%, 41.2 ± 7.6% in each
measurement item). There were no such changes in the CON group. Their results suggest that a whole-body LST resistance training regimen is as effective for muscular hypertrophy and strength gain as HN resistance training.

**Studies pertaining to upper and lower body strength**

*Szymanski et al. (2007)* examined the effect of 12 weeks of medicine ball training on high school baseball players. Forty-nine baseball players (age 15.4 +/- 1.2 years) were randomly assigned using a stratified sampling technique to 1 of 2 groups. Group 1 (n = 24) and group 2 (n = 25) performed the same full-body resistance exercises according to a stepwise periodized model and took 100 bat swings a day, 3 days per week, with their normal game bat for 12 weeks. Group 2 performed additional rotational and full-body medicine ball exercises 3 days per week for 12 weeks. Pre- and post-testing consisted of a 3 repetition maximum (RM) dominant and nondominant torso rotational strength and sequential hip-torso-arm rotational strength (medicine ball hitter’s throw). A 3RM parallel squat and bench press were measured at 0 and after 4, 8, and 12 weeks of training. Although both groups made statistically significant increases (p > 0.05) in dominant (10.5 vs. 17.1%) and nondominant (10.2 vs. 18.3%) torso rotational strength and the
medicine ball hitter's throw (3.0 vs. 10.6%), group 2 showed significantly greater increases in all 3 variables than group 1. Furthermore, both groups made significant increases in predicted 1RM parallel squat and bench press after 4, 8, and 12 weeks of training; however, there were no differences between groups. These data indicate that performing a 12-week medicine ball training program in addition to a stepwise periodized resistance training program with bat swings provided greater sport-specific training improvements in torso rotational and sequential hip-torso-arm rotational strength for high school baseball players.

Faigenbaum, (2000) stated that strength training has proven to be a safe and effective method of conditioning for adults, and it now appears that a growing number of children and adolescents also are training to improve their health, fitness, and sports performance. Although much of what we understand about the stimulus of strength exercise has been gained by exploring the responses of adults to various training protocols, research into the effects of strength exercise on children and adolescents has increased in recent years. Despite the contention that strength training was inappropriate or dangerous for young weight trainers, the safety and effectiveness
of youth strength training are now well documented and the qualified acceptance of youth strength training by medical and fitness organizations is becoming universal. It is important to encourage young people to be physically active. Not only does a sedentary lifestyle early in life appear to track into adulthood, a physically active lifestyle during childhood and adolescence may help to prevent some chronic diseases later in life. It has been recommended that children and adolescents be physically active on all, or most, days of the week, as part of play, games, sports, work, transportation, recreation, physical education or planned exercise. Although a variety of physical activities should be recommended, the purpose of this article is to discuss the trainability of muscular strength in children and adolescents, to highlight the potential benefits and concerns associated with youth strength training, and to outline strength training guidelines for young weight trainers. By definition, the term strength training (also known as resistance training) refers to a specialized method of physical conditioning that is used to increase one's ability to exert or resist force. The term strength training should be distinguished from the competitive sports of weightlifting, powerlifting, and bodybuilding.
Faigenbaum, et al., (2001) examined the effects of 4 different resistance training protocols on upper-body strength and local muscle endurance development in children. Untrained boys and girls (mean +/- SD age, 8.1 +/- 1.6 years) trained twice per week for 8 weeks using child-sized weight machines and medicine balls weighing 1-2.5 kg. In addition to general conditioning exercises, subjects in each exercise group performed 1 set of the following exercise protocols for upperbody conditioning: 6-8 repetitions with a heavy load on the chest press exercise (HL, n = 15); 13-15 repetitions with a moderate load on the chest press exercise (ML, n = 16); 6-8 repetitions with a heavy load on the chest press exercise immediately followed by 6-8 medicine ball chest passes (CX, n = 12); or 13-15 medicine ball chest passes (MB, n = 11). Twelve children served as nontraining controls (CT). After training, only the ML and CX groups demonstrated significant (p < 0.05) improvements in 1RM chest press strength (16.8% and 16.3%, respectively) as compared with the CT group. Local muscle endurance, as determined by the number of repetitions performed posttraining on the chest press exercise with the pretraining 1RM load, significantly increased in the ML group (5.9 +/- 3.2 repetitions) and CX group (5.2 +/- 3.6 repetitions) as compared with the CT
group. In terms of enhancing the upper-body strength and local muscle endurance of untrained children, their findings favor the prescription of higher-repetition training protocols during the initial adaptation period.

**Faigenbaum, (2007)** stated regarding the stimulus of resistance exercise has been gained by exploring the responses of adults to various training protocols, research into the effects of resistance exercise on children and adolescents has increased over the past decade. Despite outdated concerns that resistance training was ineffective or unsafe for youth, research increasingly suggests that resistance training can be a safe and effective method of exercise for children and adolescents provided that appropriate training guidelines are followed. In addition to enhancing motor skills and sports performance, regular participation in a youth resistance training program has the potential to positively influence several measurable indices of health. It helps strengthen bone, facilitate weight control, enhance psychosocial well-being, and improve one's cardiovascular risk profile. Furthermore, a stronger musculoskeletal system will enable boys and girls to perform life's daily activities with more energy and vigor and may increase a young athlete's resistance to sports-related injuries.
Along with other types of physical activity, a properly designed youth resistance training program can offer observable health value to children and adolescents when appropriately prescribed and supervised.

**Kraemer, et al., (2001)** studied the effects of resistance training programs on strength, power, and military occupational task performances in women were examined. To achieve the purpose untrained women aged (mean ± SD) 23 ± 4 yr were matched and randomly placed in total- (TP, N 5 17 and TH, N 5 18) or upper-body resistance training (UP, N 5 18 and UH, N 5 15), field (FLD, N 5 14), or aerobic training groups (AER, N 5 11). Two periodized resistance training programs (with supplemental aerobic training) emphasized explosive exercise movements using 3- to 8-RM training loads (TP, UP), whereas the other two emphasized slower exercise movements using 8- to 12-RM loads (TH, UH). The FLD group performed plyometric and partner exercises. Subjects were tested for body composition, strength, power, endurance, maximal and repetitive box lift, 2-mile loaded run, and U.S. Army Physical Fitness Tests before (T0) and after 3 (T3) and 6 months of training (T6). For comparison, untrained men (N 5 100) (MEN) were tested once. The result showed that specific training programs resulted in significant increases in
body mass (TP), 1-RM squat (TP, TH, FLD), bench press (all except AER), high pull (TP), squat jump (TP, TH, FLD), bench throw (all except AER), squat endurance (all except AER), 1-RM box lift (all except aerobic), repetitive box lift (all), push-ups (all except AER), sit-ups (all except AER), and 2-mile run (all). It is concluded that strength training improved physical performances of women over 6 months and adaptations in strength, power, and endurance were specific to the subtle differences (e.g., exercise choice and speeds of exercise movement) in the resistance training programs (strength/power and strength/hypertrophy). Upper- and total-body resistance training resulted in similar improvements in occupational task performances, especially in tasks that involved upper-body musculature. Finally, gender differences in physical performance measures were reduced after resistance training in women, which underscores the importance of such training for physically demanding occupations.

Mangine et al. (2008) investigated the additive effects of ballistic training to a traditional heavy resistance training program on upper- and lower-body maximal strength. Seventeen resistance-trained men were randomly assigned to 1 of 2 groups: (i) a combined ballistic and heavy resistance training group
(COM; age = 21.4 ± 1.7 years, body mass = 82.7 ± 15.1 kg) or (ii) a heavy resistance training group (HR; age = 20.1 ± 1.2 years, body mass = 81.0 ± 9.2 kg) and subsequently participated in an 8-week periodized training program. Training was performed for 3 days a week, that is, 6-8 exercises per workout (6-8 traditional exercises for HR; 4-6 traditional + 2 ballistic exercises in COM) for 3-8 repetitions. A significant increase in 1-repetition maximum (1RM) squat was shown in both groups (COM = 15.2%; HR = 17.3%) with no difference observed between groups. However, 1RM bench press increased to a significantly greater extent (P = 0.04) in COM than HR (11.6% vs. 7.1%, respectively). For peak power attained during the jump squat, an interaction (P = 0.02) was observed where the 5.4% increase in COM and -3.2% reduction in HR were statistically significant. Nonsignificant increases were observed in peak plyometric push-up power in COM (8.5%) and HR (3.4%). Lean body mass increased significantly in both groups, with no between-group differences observed. Their results support the inclusion of ballistic exercises into a heavy resistance training program for increasing 1RM bench press and enhancing lower-body power.

Bartolomei et al. (2014) compared 2 different periodization models in strength and power athletes. Twenty-four
experienced resistance trained men were randomly assigned to either a block periodization training program (BP; age = 24.2 ± 3.1 years, body mass = 78.5 ± 11.0 kg, height = 177.6 ± 4.9 cm) or to a traditional periodization program (TP; age = 26.2 ± 6.0 years, body mass = 80.5 ± 13.3 kg, height = 179.2 ± 4.6). Participants in both training programs performed 4 training sessions per week. Each training program consisted of the same exercises and same volume of training (total resistance lifted per session). The difference between the groups was in the manipulation of training intensity within each training phase.

Strength and power testing occurred before training (PRE) and after 15 weeks (POST) of training. Magnitude-based inferences were used to compare strength and power performance between the groups. Participants in BP were more likely (79.8%) to increase the area under the force-power curve than TP. Participants in BP also demonstrated a likely positive (92.76%) decrease in the load corresponding to maximal power at the bench press compared with TP group, and a possible improvement (~60%) in maximal strength and power in the bench press. No significant changes were noted between groups in lower-body strength or jump power performance after the 15-week training period. Results of their study indicate that BP may
enhance upper-body power expression to a greater extent than TP with equal volume; however, no differences were detected for lower-body performance and body composition measures.

**Kell (2011)** studied the response of previously resistance-trained male and female recreational athletes with a traditionally periodized resistance training program. Sixty subjects (age = 22.8 ± 4.5 years) were assigned to 3 groups: male training (MT), n = 20; female training (FT), n = 20; and control, n = 20 (men, n = 10; women, n = 10). The MT and FT groups completed 12 weeks of traditional periodized strength training, with strength testing at baseline and on weeks 8 and 12. The training programs were identical (e.g., rest time, exercises, volume, and intensity) in both groups. In weeks 1 and 2, the FT and MT groups were trained 3 d·wk⁻¹ (324 repetitions [reps]·wk⁻¹) and thereafter 4 d·wk⁻¹ (mean 642 reps·wk⁻¹). The mean volume and intensity over the 12 weeks was 571 reps·wk⁻¹ and 69.7% of 1 repetition maximum. Results indicated that the men were significantly (p ≤ 0.05) stronger in absolute terms at baseline and on weeks 8 and 12. The FT group (increase = 26.2% on week 8 and 38.1% at week 12) made significantly (p ≤ 0.05) greater percent increases in strength than the MT group (increase = 17.7% at week 8 and 28.0% at week 12). The FT and MT groups
made significant \( p \leq 0.05 \) changes in relative strength at all time points, but the MT group demonstrated greater relative strength on lateral pull-down and dumbbell shoulder press. In practical terms, the men were absolutely stronger than the women, but the women were more responsive to the periodized resistance training program. Twelve weeks of traditionally periodized resistance training induced meaningful strength gains in women (\( \geq 30\% \)) and men (\( \geq 25\% \)) with prior (approximately 11 months) non periodized resistance training experience.

Prestes et al. (2009) determined the most effective periodization model for strength and hypertrophy is an important step for strength and conditioning professionals. The aim of their study was to compare the effects of linear (LP) and daily undulating periodized (DUP) resistance training on body composition and maximal strength levels. Forty men aged 21.5 ± 8.3 and with a minimum 1-year strength training experience were assigned to an LP (n = 20) or DUP group (n = 20). Subjects were tested for maximal strength in bench press, leg press 45°, and arm curl (1 repetition maximum [RM]) at baseline (T1), after 8 weeks (T2), and after 12 weeks of training (T3). Increases of 18.2 and 25.08% in bench press 1 RM were observed for LP and DUP groups in T3 compared with T1, respectively \( (p \leq 0.05) \). In
leg press $45^\circ$, LP group exhibited an increase of 24.71% and DUP of 40.61% at T3 compared with T1. Additionally, DUP showed an increase of 12.23% at T2 compared with T1 and 25.48% at T3 compared with T2. For the arm curl exercise, LP group increased 14.15% and DUP 23.53% at T3 when compared with T1. An increase of 20% was also found at T2 when compared with T1, for DUP. Although the DUP group increased strength the most in all exercises, no statistical differences were found between groups. In conclusion, undulating periodized strength training induced higher increases in maximal strength than the linear model in strength-trained men. For maximizing strength increases, daily intensity and volume variations were more effective than weekly variations.

**Spineti et al. (2010)** examined the influence of exercise order on strength and muscle volume (MV) after 12 weeks of nonlinear periodized resistance training. The participants were randomly assigned into 3 groups. One group began performing large muscle group exercises and progressed to small muscle group exercises (LG-SM), whereas another group started with small muscle group exercises and advanced to large muscle group exercises (SM-LG). The exercise order for LG-SM was bench press (BP), machine lat pull-down (LPD), triceps extension
(TE), and biceps curl (BC). The order for the SM-LG was BC, TE, LPD, and BP. The third group did not exercise and serve as a control group (CG). Training frequency was in 2 sessions per week with at least 72 hours of rest between sessions. Muscle volume was assessed at baseline and after 6 weeks and 12 weeks of training by ultrasound techniques. One repetition maximum strength for all exercises was assessed at baseline and after 12 weeks of training. Effect size data demonstrated that differences in strength and MV were exhibited based on exercise order. Both training groups demonstrated greater strength improvements than the CG, but only BP strength increased to a greater magnitude in the LG-SM group as compared with the SM-LG. In all other strength measures (LPD, TE, and BC), the SM-LG group showed significantly greater strength increases. Triceps MV increased in the SM-LG group; however, biceps MV did not differ significantly between the training groups. They concluded that an exercise is important for the training goals of a program, then it should be placed at the beginning of the training session, regardless of whether or not it is a large muscle group exercise or a small muscle group exercise.

**Moraes et al. (2013)** compared 2 models of resistance training (RT) programs, nonperiodized (NP) training and daily
nonlinear periodized (DNLP) training, on strength, power, and flexibility in untrained adolescents. Thirty-eight untrained male adolescents were randomly assigned to 1 of 3 groups: a control group, NP RT program, and DNLP program. The subjects were tested pretraining and after 4, 8, and 12 weeks for 1 repetition maximum (1RM) resistances in the bench press and 45° leg press, sit and reach test, countermovement vertical jump (CMVJ), and standing long jump (SLJ). Both training groups performed the same sequence of exercises 3 times a week for a total of 36 sessions. The NP RT consisted of 3 sets of 10–12RM throughout the training period. The DNLP training consisted of 3 sets using different training intensities for each of the 3 training sessions per week. The total volume of the training programs was not significantly different. Both the NP and DNLP groups exhibited a significant increase in the 1RM for the bench press and 45° leg press posttraining compared with that pretraining, but there were no significant differences between groups (p ≤ 0.05). The DNLP group’s 1RM changes showed greater percentage improvements and effect sizes. Training intensity for the bench press and 45° leg press did not significantly change during the training. In the CMVJ and SLJ tests, NP and DNLP training showed no significant change. The DNLP group showed
a significant increase in the sit and reach test after 8 and 12 weeks of training compared with pretraining; this did not occur with NP training. In summary, in untrained adolescents during a 12-week training period, a DNLP program can be used to elicit similar and possible superior maximal strength and flexibility gains compared with an NP multiset training model.

**Plyometric training**

**Studies related to body composition**

MacDonald, Lamont and Garner (2012) stated that complex training (CT; alternating between heavy and lighter load resistance exercises with similar movement patterns within an exercise session) is a form of training that may potentially bring about a state of postactivation potentiation, resulting in increased dynamic power (Pmax) and rate of force development during the lighter load exercise. Such a method may be more effective than either modality, independently for developing strength. The purpose of the research was to compare the effects of resistance training (RT), plyometric training (PT), and CT on lower body strength and anthropometrics. Thirty recreationally trained college-aged men were trained using 1 of 3 methods: resistance, plyometric, or complex twice weekly for 6 weeks. The participants were tested pre, mid, and post to assess back squat
strength, Romanian dead lift (RDL) strength, standing calf raise (SCR) strength, quadriceps girth, triceps surae girth, body mass, and body fat percentage. Diet was not controlled during this study. Statistical measures revealed a significant increase for squat strength \((p = 0.000)\), RDL strength \((p = 0.000)\), and SCR strength \((p = 0.000)\) for all groups pre to post, with no differences between groups. There was also a main effect for time for girth measures of the quadriceps muscle group \((p = 0.001)\), the triceps surae muscle group \((p = 0.001)\), and body mass \((p = 0.001; \text{ post hoc revealed no significant difference})\). There were main effects for time and group × time interactions for fat-free mass % (RT: \(p = 0.031\); PT: \(p = 0.000\)). They suggested that CT mirrors benefits seen with traditional RT or PT. Moreover, CT revealed no decrement in strength and anthropometric values and appears to be a viable training modality.

**Sedano et al. (2009)** examined whether explosive strength, kicking speed, and body composition are affected by a 12-week plyometric training program in elite female soccer players. The hypothesis was that their program would increase the jumping ability and kicking speed and that these gains could be maintained by means of regular soccer training only. Twenty adult female players were divided into 2 groups: control group
(CG, n = 10, age 23.0 +/- 3.2 yr) and plyometric group (PG, n = 10; age 22.8 +/- 2.1 yr). The intervention was carried out during the second part of the competitive season. Both groups performed technical and tactical training exercises and matches together. However, the CG followed the regular soccer physical conditioning program, which was replaced by a plyometric program for PG. Neither CG nor PG performed weight training. Plyometric training took place 3 days a week for 12 weeks including jumps over hurdles, drop jumps (DJ) in stands, or horizontal jumps. Body mass, body composition, countermovement jump height, DJ height, and kicking speed were measured on 4 separate occasions. The PG demonstrated significant increases (p < 0.05) in jumping ability after 6 weeks of training and in kicking speed after 12 weeks. There was no significant time x group interaction effects for body composition. They concluded that a 12-week plyometric program can improve explosive strength in female soccer players and that these improvements can be transferred to soccer kick performance in terms of ball speed. However, players need time to transfer these improvements in strength to the specific task. Regular soccer training can maintain the improvements from a plyometric training program for several weeks.
Marković et al. (2005) compared the effects of sprint and plyometric training on morphological Characteristics of physically active men. One hundred and fifty one physical education students (18-24 years of age) were allocated into one of three groups: the plyometric group (PG; \(n = 50\)), the sprint group (SG; \(N = 50\)), and the control group (CG; \(n = 51\)). Both experimental groups participated in a training programme 3 times a week for 10 weeks. SG performed maximal sprints for distances between 10 and 50 meters, while The training programme in PG consisted of hurdle jumps and drop jumps. Anthropometric measurement was performed in the week before and the week after the experiment. There were no significant differences \((P > 0.05)\) in magnitude of changes in any of the analysed anthropometric variables between the groups. However, a significant decrease \((P < 0.0167)\) in the percentage of body fat (6.1%) was found in SG. They also found a significant decrease \((P < 0.0167)\) in body mass (1%), fat-free mass (0.4%) and body mass index (0.9%) for the SG, but the magnitude of these changes was rather low. They conclude that the short-term explosive-type training programmes in which muscles operate in the fast stretch-shortening cycle conditions (i.e., sprinting,
jumping) have a limited potential to induce morphological changes in physically active men.

Studies related to speed, agility and power

Rimmer and Sleivert (2000) studied the effects of a plyometric programme on sprinting performance in a group of 26 male participants (age: 24 ± 4 years), consisting of 22-rugby players and four touch-rugby players, playing at elite or under-21 level of competition. Participants were divided into a plyometric-group (n=10) performing sprint-specific plyometric exercises, a sprint-group (n=7), performing sprints and a control-group (n=9). All three groups performed sprint tests before and after the eight week intervention (15-sessions), consisting of three to six maximal sprint test efforts between 10- and 40-metres (m). During the 40-metre sprint, time was also recorded, at the 10-, 20-, 30-, and 40-m marks. The stride frequency was determined with a video camera in the 10- and 40-m sprints. Ground reaction time was measured with a force plate platform between the seven and 10-m marks, and also between the 37- and 40-m marks. The plyometric-group showed a significant decrease in time over the 0–10-m (2.6%; p=0.001) and 0–40-m (2.2%; p=0.001) distances, with the greatest improvement within the first 10-m of the sprint. These improvements were not
significantly different from those observed in the sprint-group. However, there were no significant improvements in the sprint-group. The control group also showed no improvements in sprint times. There were no significant changes in stride length or frequency for any of the groups during the study. PT-group was the only group to show a significant decrease (4.4%) in ground contact time, and this only occurred between the 37-m and 40-m mark. The results showed that sprint specific plyometric exercises can improve sprint performance to the same extent as regular sprint training, especially over the first 10-m (acceleration phase) of the sprint, possibly due to shorter ground reaction times. In sports where speed up to 40-m are important, benefits would be derived by adding sprint-specific exercises to a regular sprint training programme, especially when acceleration adds to enhanced performance.

**Lehnert, Lamrova and Elfmark (2009)** studied the plyometric training effects on speed and explosive power predispositions during and after the end of the training program. The program was applied to a group of female youth volleyball players (n = 11) twice a week during an eight week period. Their actual level of explosive power and locomotor speed was evaluated before, during and after the intervention was
completed. The levels were determined with the following tests: the standing vertical jump, the vertical jump with an approach and the shuttle run for $6 \times 6$ m. There were positive changes in the average values of test scores during the period of testing, but the dynamics of the changes in the explosive power and the speed were different. Other increases in all the characteristics were noticeable when the final measurements were made six weeks after the completion of the training program. Examination of the differences in the test scores by the follow up group, before the beginning and six weeks after finishing the intervention, was centred on objectively and statistically important changes in the volleyball players’ motor predispositions ($p < .05$). The results of the program supported the opinion that plyometric exercises are effective tools in the development of explosive power and speed in young athletes.

**Benito-Martínez, et al., (2011)** determined the performance evolution of a group of athletes after 8 weeks of training that combined electrostimulation (NM ES) and plyometrics (PT). 78 medium level sprinter athletes participated, 40 women and 38 men (age, 15.9±1.4 years old, body mass index, 20.5±1.68 kg/m2; weight 58.53±8.05 kg; height, 1.68±0.07 m). The sample was randomized into four groups
[Control (PT only), NM ES + PT, PT + NM ES, and Simultaneous (plyometric jumps were performed through the passage of current). Improvements were obtained in the Abalakov jump of 3.57% \((p<0.01)\), 13.51% \((p<0.001)\), 1.23% \((p<0.01)\), and 0.77%, and in the sprint of 0.45%, 3.87% \((p<0.05)\), 4.56% \((p<0.01)\) and 7.26% \(p<0.001\) for the control group, NM ES + PT group, PT + NM ES group, and Simultaneous group, respectively. They concluded that a) improvement in vertical jump requires the application of the NM ES prior to PT; b) the sprinter athlete must combine the workout simultaneously or apply the ES after the PT training; and c) in sportspeople that require improvement in both the vertical jump and speed tests (e.g. basketball) the simultaneous method is not recommended, the order of application of NM ES and PT being non-determinant. Finally, the time needed to obtain significant improvement in strength training through a combination of NM ES and PT is substantially lower (15 days) than the time needed to improve speed (30 days).

Kubo, et al., (2007) investigated the effects of plyometric and weight training protocols on the mechanical properties of muscle-tendon complex and muscle activities and performances during jumping. To fulfill the purpose ten subjects were selected and completed 12 wk \((4 \text{ d·wk}^{-1})\) of a unilateral training program.
for plantar flexors. They performed plyometric training on one side (PT; hopping and drop jump using 40% of 1RM) and weight training on the other side (WT; 80% of 1RM). Tendon stiffness was measured using ultrasonography during isometric plantar flexion. Three kinds of unilateral jump heights using only ankle joint (squat jump: SJ; countermovement jump: CMJ; drop jump: DJ) on sledge apparatus were measured. During jumping, electromyographic activities were recorded from plantar flexors and tibial anterior muscle. Joint stiffness was calculated as the change in joint torque divided by the change in ankle angle during eccentric phase of DJ. The result showed that tendon stiffness increased significantly for WT, but not for PT. Conversely, joint stiffness increased significantly for PT, but not for WT. Whereas PT increased significantly jump heights of SJ, CMJ, and DJ, WT increased SJ only. The relative increases in jump heights were significantly greater for PT than for WT. However, there were no significant differences between PT and WT in the changes in the electromyographic activities of measured muscles during jumping. Their results indicated that the jump performance gains after plyometric training are attributed to changes in the mechanical properties of muscle-tendon complex, rather than to the muscle activation strategies.
Markovic, et al., (2007) evaluated the effects of sprint training on muscle function and dynamic athletic performance and to compare them with the training effects induced by standard plyometric training. Male physical education students were assigned randomly to 1 of 3 groups: sprint group (SG; n = 30), plyometric group (PG; n = 30), or control group (CG; n = 33). Maximal isometric squat strength, squat-and counter-movement jump (SJ and CMJ) height and power, drop jump performance from 30-cm height, and 3 athletic performance tests (standing long jump, 20-m sprint, and 20-yard shuttle run) were measured prior to and after 10 weeks of training. Both experimental groups trained 3 days a week; SG performed maximal sprints over distances of 10-50 m, whereas PG performed bounce-type hurdle jumps and drop jumps. Participants in the CG group maintained their daily physical activities for the duration of the study. Both SG and PG significantly improved drop jump performance (15.6 and 14.2%), SJ and CMJ height (~10 and 6%), and standing long jump distance (3.2 and 2.8%), whereas the respective effect sizes (ES) were moderate to high and ranged between 0.4 and 1.1. In addition, SG also improved isometric squat strength (10%; ES = 0.4) and SJ and CMJ power (4%; ES = 0.4, and 7%; ES = 0.4), as well as sprint (3.1%; ES = 0.9) and agility (4.3%; ES = 1.1)
performance. They concluded that short-term sprint training produces similar or even greater training effects in muscle function and athletic performance than does conventional plyometric training. Their study provided support for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

**Thomas, French and Hayes (2009)** compared the effects of two plyometric training techniques on power and agility in youth soccer players. Twelve males from a semiprofessional football club’s academy (age = 17.3 ± 0.4 years, stature = 177.9 ± 5.1 cm, mass = 68.7 ± 5.6 kg) were randomly assigned to 6 weeks of depth jump (DJ) or countermovement jump (CMJ) training twice weekly. Participants in the DJ group performed drop jumps with instructions to minimize ground-contact time while maximizing height. Participants in the CMJ group performed jumps from a standing start position with instructions to gain maximum jump height. Posttraining, both groups experienced improvements in vertical jump height ($p < 0.05$) and agility time ($p < 0.05$) and no change in sprint performance ($p > 0.05$). There were no differences between the treatment groups ($p > 0.05$). Their study concluded that both DJ and CMJ
plyometrics are worthwhile training activities for improving power and agility in youth soccer players.

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

**Markovic (2007)** examined the precise effect of plyometric training (PT) on vertical jump height in healthy individuals. Meta-analyses of randomised and non-randomised controlled trials that evaluated the effect of PT on four typical vertical jump height tests were carried out: squat jump (SJ); countermovement jump (CMJ); countermovement jump with the arm swing (CMJA); and drop jump (DJ). Studies were identified by computerised and manual searches of the literature. Data on changes in jump height for the plyometric and control groups were extracted and statistically pooled in a meta-analysis, separately for each type of jump. A total of 26 studies yielding 13 data points for SJ, 19 data points for CMJ, 14 data points for CMJA and 7 data points for DJ met the initial inclusion criteria. The pooled estimate of
the effect of PT on vertical jump height was 4.7% (95% CI 1.8 to 7.6%), 8.7% (95% CI 7.0 to 10.4%), 7.5% (95% CI 4.2 to 10.8%) and 4.7% (95% CI 0.8 to 8.6%) for the SJ, CMJ, CMJA and DJ, respectively. When expressed in standardised units (ie, effect sizes), the effect of PT on vertical jump height was 0.44 (95% CI 0.15 to 0.72), 0.88 (95% CI 0.64 to 1.11), 0.74 (95% CI 0.47 to 1.02) and 0.62 (95% CI 0.18 to 1.05) for the SJ, CMJ, CMJA and DJ, respectively. PT provides a statistically significant and practically relevant improvement in vertical jump height with the mean effect ranging from 4.7% (SJ and DJ), over 7.5% (CMJA) to 8.7% (CMJ). These results justified the application of PT for the purpose of development of vertical jump performance in healthy individuals.

Wilson, et al., (1993) carried out this study to determine 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 wk performing either heavy squat lifts, depth jumps, or weighted squat jumps. All subjects were tested prior to training, after 5 wk of training and on the completion of the training period. The test items included 1) 30-m sprint, 2) vertical jumps performed with and without a countermovement, 3) maximal cycle test, 4) isokinetic 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 statistically significant (P < 0.05) improvements on most test items and producing statistically superior results to the two other training modalities on the jumping and isokinetic tests.

Sáez-Sáez De Villarreal, et al., (2010) identified and stated that majority of the research suggests plyometric training (PT) improves maximal strength performance as measured by 1RM, isometric MVC or slow velocity isokinetic testing. However, the effectiveness of PT depends upon various factors. A meta-analysis of 15 studies with a total of 31 effect sizes (ES) was carried out to analyse the role of various factors on the effects of PT on strength performance. The inclusion criteria for the analysis were: (a) studies using PT programs for lower limb
muscles; (b) studies employing true experimental design and valid and reliable measurements; (c) studies including sufficient data to calculate ES. When subjects can adequately follow plyometric exercises, the training gains are independent of fitness level. Subjects in either good or poor physical condition, benefit equally from plyometric work, also men obtain similar strength results to women following PT. In relation to the variables of program design, training volume of less than 10 weeks and with more than 15 sessions, as well as the implementation of high-intensity programs, with more than 40 jumps per session, were the strategies that seem to maximize the probability to obtain significantly greater improvements in performance ($p < 0.05$). In order to optimise strength enhancement, the combination of different types of plyometrics with weight-training would be recommended, rather than utilizing only one form ($p < 0.05$). The responses identified in the analysis are essential and should be considered by the strength and conditioning professional with regard to the most appropriate dose–response trends for PT to optimise strength gains.

Adams, et al., (1992) stated that explosive leg power is a key ingredient to maximizing vertical jump performance. In
training, the athlete must use the most effective program to optimize leg power development. The purpose of their study was to compare the effectiveness of three training programs 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 four groups: S, P, SP or control (C). The subjects were trained two days a week for a total of seven weeks, which consisted of a one-week technique learning period followed by a six-week periodized S, P or SP training program. Hip and thigh power were tested before and after training using the vertical jump test, and the alpha level was set at 0.05. Statistical analysis of the data revealed a significant increase in hip and thigh power production, as measured by vertical jump, within all three treatment groups. The SP group achieved a statistically greater improvement ($p < 0.0001$) than the S or P groups alone. 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. They found that both S and P training are necessary for improving hip and thigh power production as measured by vertical jumping ability.
Faigenbaum, et al., (2007) compared the effects of a six week training period of combined plyometric and resistance training (PRT, n = 13) or resistance training alone (RT, n = 14) on fitness performance in boys (12-15 yr). The RT group performed static stretching exercises followed by resistance training whereas the PRT group performed plyometric exercises followed by the same resistance training program. The training duration per session for both the groups was 90 min. At baseline and after training all participants were tested on the vertical jump, long jump, medicine ball toss, 9.1 m sprint, pro agility shuttle run and flexibility. The PRT group made significantly (p < 0.05) greater improvements than RT in long jump (10.8 cm vs. 2.2 cm), medicine ball toss (39.1 cm vs. 17.7 cm) and pro agility shuttle run time (-0.23 sec vs. -0.02 sec) following training. They suggested that the addition of plyometric training to a resistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of upper and lower body power in boys.

Dodd and Alvar (2007) carried out a study 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; 0.15; -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). They concluded that complex training can provide strength and conditioning professionals 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.

Miller, et al., (2006) studied the impact of plyometric training for six weeks on agility. Subjects were divided into two groups, a plyometric training and a control group. The plyometric training group performed in a six week plyometric training program and the control group did not perform any plyometric training techniques. All subjects participated in two agility tests: T-test and Illinois Agility Test, and a force plate test for ground reaction times both pre and post testing. Univariate ANCOVAs were conducted to analyze the change scores (post – pre) in the independent variables by group (training or control) with pre scores as covariates. The Univariate ANCOVA revealed a significant group effect $F_{2,26} = 25.42, p=0.0000$ for the T-test agility measure. For the Illinois Agility test, a significant group effect $F_{2,26} = 27.24, p = 0.000$ was also found. The plyometric training group had quicker posttest times compared to the control group for the agility tests. A significant group effect $F_{2,26} = 7.81, p = 0.002$ was found for the Force Plate test. The plyometric training group reduced time on the ground on the posttest compared to the control group. They found that
plyometric training can be an effective training technique to improve an athlete’s agility.

**Robinson and Owens (2004)** conducted a study to evaluate the increase in agility during preparatory phase for which their program that targets fundamental techniques and skills required for straight ahead speed, directional changes, and lower body power development to be used during a collegiate athlete’s non-traditional season. The goal of their program is to teach generalized movement patterns and build a solid foundation that can be used by individual sport coaches during their traditional season.

**Young, McDowell and Scarlett (2001)** tried to identify whether 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 6 agility tests with 2-5 changes of direction at various angles. The subjects participated in 2 training sessions per week for 6 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, the 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. They concluded that straight speed and agility training methods are specific and produce limited transfer to the other. Their findings have implications for the design of speed and agility training and testing protocols.

Alricsson, Harms-Ringdahl and Werner (2001) investigated the reliability of two sports related functional tests, a speed test (slalom-test) and an agility test (hurdle-test). Eleven athletes aged 11 years (8 boys, 3 girls) participated voluntarily in the study. All subjects completed four different test sessions for both the slalom-test and the hurdle-test using six standard track hurdles placed at 2-m intervals along a 12-m length of track. There were no significant differences between testing sessions for either the slalom-test ($P=0.99$) or the hurdle-test ($P=0.96$), showing no systematic variation between test times. The intraclass correlation coefficients were 0.96 and 0.90 respectively, indicating a good reliability. They concluded that
the slalom-test and the hurdle-test are reliable sports related functional tests for measuring speed and agility in groups of young athletic individuals.

Complex training has gained popularity as a training strategy combining weight training and plyometric training. Anecdotal reports recommend training in this fashion in order to improve muscular power and athletic performance. Recently, several studies have examined complex training. Despite the fact that questions remain about the potential effectiveness and implementation of this type of training, results of recent studies are useful in guiding practitioners in the development and implementation of complex training programs. In some cases, research suggests that complex training has an acute ergogenic effect on upper body power and the results of acute and chronic complex training include improved jumping performance. Improved performance may require three to four minutes rest between the weight training and plyometrics sets and the use of heavy weight training loads (Ebben, 2002).

Bal, Kaur and Singh (2011) assessed the effects of a short term plyometric training program on agility in young basketball players. A group of Thirty (N=30) male basketball players aged 18 – 24 years, who participated in intercollege basketball
competitions organized by the Department of Sports, Guru Nanak Dev University, volunteered to participate in this study. Their mean height, weight, and age were 1.87±0.06m, 75.5±5.2kg, 22.5±0.4 years. All subjects, after having been informed about the objective and protocol of the study, gave their written consents and the study was approved by the local Committee of Ethics. The subjects were randomly assigned into two groups: experimental (E; n = 15) and control (C; n = 15). Group E was subjected to a 6-week training, 25 min a day. Student’s t-test for independent data was used to assess the between-group differences and for dependent data to assess the Post-Pre differences. Level of p≤0.05 was considered significant. The results of their study are very encouraging and demonstrate the benefits of short term plyometric training program on agility in young basketball players. They concluded that the use of plyometrics training program not only to break the monotony of training, but it can also improve the strength of basketball players.

Asadi and Arazi (2012) evaluated the effects of high-intensity plyometric training program on dynamic balance, agility, vertical jump, and sprint performance in young male basketball players. To fulfill the purpose sixteen semi-
professional basketball players participated in this study. Subjects were divided into two groups: plyometric training (PL; n = 8) and control group (CG; n = 8). Plyometric training took place 2 days a week for 6 weeks including depth jump, squat depth jump, and depth jump to standing long jump. Star Excursion Balance Test (SEBT), vertical jump (VJ), standing long jump (SLJ), 4 × 9- m shuttle run, T-test, Illinois Agility Test, and 20-m sprint were measured at pre- and post-training. The result of the study showed that PL demonstrated significant improvement (P < 0.05) in VJ (~23%), SLJ (~10%), 4 × 9-m shuttle run (~7%), T-test (~9%), Illinois Agility test (~7%), and 20-m sprint (~9%) after a 6- week training and compared to CG. There were not significant changes (P > 0.05) in SEBT, but PL showed ~4% improvement. They concluded that a 6-week high-intensity plyometric program can improve power, agility, sprint and balance in young male basketball players. Also, their study provided support for coaches and basketball players who use plyometric training method at the preparation (conditioning) phase.

Shallaby (2010) studied the effectiveness of plyometric exercises on the special physical abilities and skilful performance of basketball players. It was applied to a sample of
20 players of 16 years old from El- Shoban El-Muslmeen club in Port Said. The participants were divided into two equivalent groups (experimental and control) of 10 players each. The experimental group applied the plyometric exercises and the control group applied the usual program. The program was applied for 12 weeks with 3 training units for 120 minutes each. Through the training unit, the exercises were united between the two groups except for the special physical preparation part. The experimental group performed the plyometric exercises while the control group performed the physical exercise. Then, the scientific coefficients were applied to tests using a sample outside the study sample. The scientific coefficients of constancy were between 0.764 and 0.970 and the reliability was between 0.903 and 984. The results pointed to a significant progress in the improvement percentages for the experimental group in all study tests compared to the improvement percentages of the control group, which were respectively: tests of vertical jump at 27.01%, medicine ball push (3 kg) at 20.14%, running 30m x 5n at 1.62% and shuttle running at 7.53%, which led to an improvement in the skillful performance (passing at 13.62%, dribbling at 13.46% , under-basket shooting at18.58% and lay-up at 57.97%).
Lim, et al., (2012) examined the effects of 6-week plyometric training on the agility of college badminton players. A total of 42 college co-curriculum badminton students, aged 18-20 years participated in their study. Cluster sampling was used to select the two groups of students and subsequently the groups were randomly assigned to the control (n=23, male=7, female=16) and experimental (n=19, male=8, female=11) groups. Both groups were trained according to the compulsory co-curriculum programme once a week for six weeks. Additional plyometric training was provided to the experimental group. Illinois Agility Test (IAT) was used to determine the effect of plyometric training during pre and post intervention on agility. Control and experimental groups showed significant improvement in the mean agility scores during the post test as compared with the pre test (t=-2.48; p=0.001; and t=-2.89; p<0.001 respectively). The experimental group exhibited greater improvement (7%) as compared to the control group (2.5%) (p=0.012) based on their pre test mean scores. They summarized that plyometric training improved the agility of college co-curriculum badminton players and plyometric training is recommended for training in improving agility in other sports as well.
Studies related to flexibility and abdominal endurance

Chaudhary & Jhajharia (2010) reported that there is not a single sport in the world at the competitive level for which resistance training in some or the other form is not used as conditioning exercises. Plyometric training is an excellent method of developing body power and it is proved as a very effective method for improving explosive strength. The purpose of their study was to find out the effects of plyometric exercises on selected motor abilities of university level female basketball players. The subjects, 20 female basketball players of Lakshmibai National Institute of Physical Education, Gwalior, were randomly divided in two groups, that is, experimental and control group. The age of subjects varied between 18 and 22 years. The criterion measures vertical jump, 20-m dash, movement speed, flexibility and agility in the beginning and at the end of the experimental period of 6 weeks for both the groups. The analysis of co-variance was used as a statistical technique and it was tested at 0.05 level of significance. They concluded that the plyometric training is an effective means for improving agility, flexibility vertical jump and movement speed. On the other hand, plyometric training is not an effective means for improving speed of movement (20-m dash).
Messner, et al., (1999) studied the effect of plyometric training on strength, vertical jump, flexibility and range of motion in volleyball players. To fulfill the purpose nine female I Division volleyball players were selected and plyometric training was administered during post season. The protocol followed twice a week for eight weeks. The result showed that no changes were found in a number of strength factors for the quadriceps or hamstring muscle groups. No improvements in vertical jump were recorded. The only feature of improvement was an increase in range of motion for dorsiflexion in both legs. They concluded that plyometrics training was not beneficial for female volleyball players, possibly because they had already engaged in many maximal vertical jumps as part of the sport.

Hill and Leiszler (2011) identified core stability and plyometric training and have become common elements of training programs in competitive athletes. Core stability allows stabilization of the spine and trunk of the body in order to allow maximal translation of force to the extremities. Plyometric training is more dynamic and involves explosive-strength training. Integration of these exercises theoretically begins with core stabilization using more static exercises, allowing safe and effective transition to plyometric exercises. Both core
strengthening and plyometric training have demonstrated mixed but generally positive results on injury prevention rehabilitation of certain types of injuries. Improvement in performance compared to other types of exercise is unclear at these times. Their article discussed the theory and strategy behind core stability and plyometric training; reviews the literature on injury prevention, rehabilitation of injury, and performance enhancement with these modalities; and discussed the evaluation and rehabilitation of core stability.

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

Cowley and Swensen (2008) identified and recognized the link between core stability and back and lower extremity injury in sport, however additional field tests that assess the strength
and power component of core stability are needed to identify athletes at risk of such injury. For which they developed and tested the reliability of the front and side abdominal power tests (FAPT and SAPT), which were adapted from plyometric medicine ball exercises. The FAPT and SAPT were performed by explosively contracting the core musculature using the arms as a lever to project a medicine ball. Twenty-four untrained young women (aged 20.9 +/- 1.1 year) completed three trials each of the FAPT and SAPT on separate nonconsecutive days. The average distance the medicine ball was projected on each day was recorded; power was inferred from this measure. There was an approximately 3% increase in the mean distance between the testing sessions for the FAPT and SAPT; this was not significant and indicates there was no learning effect in the measurement protocol. Heteroscedasticity was present in the SAPT data but not the FAPT data. For the FAPT, the intraclass correlation coefficient was 0.95, standard error of measurement was 24 cm, and random error using the limits of agreement method was 67.5 cm. For the SAPT, the intraclass correlation coefficient was 0.93, mean coefficient of variation was 9.8%, and the limits of agreement ratio were 36.8%. The FAPT and SAPT displayed excellent test-retest reliability, as well as acceptable
measurement error. Their findings suggested that the FAPT and SAPT are reliable tests and may be used to assess the power component of core stability in young women.

Barber-Westin, Hermeto and Noyes (2010) evaluated the effectiveness of a tennis-specific training program on improving neuromuscular indices in competitive junior players. Tennis is a demanding sport because it requires speed, agility, explosive power, and aerobic conditioning along with the ability to react and anticipate quickly, and there are limited studies that evaluate these indices in young players after a multiweek training program. The program designed for their study implemented the essential components of a previously published neuromuscular training program and also included exercises designed to improve dynamic balance, agility, speed, and strength. Fifteen junior tennis players (10 girls, 5 boys; mean age, 13.0 +/- 1.5 years) who routinely participated in local tournaments and high-school teams participated in the 6 week supervised program. Training was conducted 3 times a week, with sessions lasting 1.5 hours that included a dynamic warm-up, plyometric and jump training, strength training (lower extremity, upper extremity, core), tennis-specific drills, and flexibility. After training, statistically significant improvements
and large-to-moderate effect sizes were found in the single-leg triple crossover hop for both legs \((p < 0.05)\), the baseline forehand \((p = 0.006)\) and backhand \((p = 0.0008)\) tests, the service line \((p = 0.0009)\) test, the 1-court suicide \((p < 0.0001)\), the 2-court suicide \((p = 0.02)\), and the abdominal endurance test \((p = 0.01)\). Mean improvements between pretrain and posttrain test sessions were 15% for the single-leg triple crossover hop, 10-11% for the baseline tests, 18% for the service line test, 21% for the 1-court suicide, 10% for the 2-court suicide, and 76% for the abdominal endurance test. No athlete sustained an injury or developed an overuse syndrome as a result of the training program. The results demonstrated that their program is feasible, low in cost, and appears to be effective in improving the majority of neuromuscular indices tested. They accomplished their goal of developing training and testing procedures that could all be performed on the tennis court.

**Studies related to combined strength and plyometric training**

*Faigenbaum, et al., (2007)* compared the effects of a six week training period of combined plyometric and resistance training \((\text{PRT, } n = 13)\) or resistance training alone \((\text{RT, } n = 14)\) on fitness performance in boys \((12-15 \text{ yr})\). The RT group performed static stretching exercises followed by resistance training
whereas the PRT group performed plyometric exercises followed by the same resistance training program. The training duration per session for both groups was 90 min. At baseline and after training all participants were tested on the vertical jump, long jump, medicine ball toss, 9.1 m sprint, pro agility shuttle run and flexibility. The PRT group made significantly (p < 0.05) greater improvements than RT in long jump (10.8 cm vs. 2.2 cm), medicine ball toss (39.1 cm vs. 17.7 cm) and pro agility shuttle run time (-0.23 sec vs. -0.02 sec) following the training. Their findings suggest that the addition of plyometric training to a resistance training program may be more beneficial than resistance training and static stretching for enhancing selected measures of upper and lower body power in boys.

**Bauer, Thayer and Baras (1990)** assessed the effect of a 10-week resistance and resistance-plyometrics training program on measures of lower body power and body composition. Twenty-two male and 15 female physical education students were randomly assigned to one of five groups as follows: free weights (FW, n = 8), Hydra Gym (HydraFitness, Edmonton, Alberta, Canada), (HG, n = 8), plyometrics (P, n = 8), Hydra Gym with plyometrics (HG-P, n = 6) and free weights with plyometrics (FW-P, n = 7). All groups trained three times per week with each
session lasting approximately 30 minutes. Vertical jump, percent body fat and isokinetic power variables were determined at the beginning and at the conclusion of the 10-week training program. Peak torque values, measured on the Cybex II (Lumex Corp., Bayshore, New York) at four velocity settings were expressed in terms of lean body mass (LBM). No between-group significant differences (P < 0.05) were observed for any of the test items measured. However, within each training group, there was a significant increase (P < 0.05) in peak torque measures following the training program. Their results reveal that similar increases in lower extremity power may be induced by a variety of resistance and resistance-plyometrics programs.

**Summary of Literature**

The literatures presented in three sub headings as strength training, plyometric training and combined strength and plyometric training. The studies presented above clearly show that strength training decreases percent body fat and fat mass. The training significantly increases the hypertrophy of muscle there by lean body mass increases. Similarly, strength training programme result in improvement of lower and upper extremity strength thereby it improves static balance, flexibility, core
strength, speed and power. However, no changes are elicited in agility and endurance.

Plyometric training is one of the oldest forms of training method utilized by coaches to prepare players. Plyometric training significantly decreased percentage of body fat and increased lean body mass. However, few studies state that no changes were elicited in body composition. Previous studies reported that plyometric training, sprint performance, power and agility, Upper body and lower body plyometric exercises significantly improve the explosive strength of upper and lower body. It also improves hamstring flexibility and abdominal muscular endurance; but it failed to show improvement in endurance.

Few studies showed that combined strength and plyometric have significant effect on speed, power and agility. The combined training adopted in this study was not studied in male kabaddi players. Therefore, the purpose of this study was to examine the combined effect of strength and plyometric training on body composition and physical fitness variables of male kabaddi players.