CHAPTER – II

REVIEW OF RELATED LITERATURE

A study of relevant literature is an essential step to get a full picture of what has been done with regard to the problem under study. Such a review brings out a deep and clear perspective of overall field.

The review of literature is instrumental in the selection of the topic, transaction of hypothesis and deductive reasoning leading to the problem. It helps to get a clear idea and supports the findings with regard to the problem under study.

The following materials collected from the views expressed by the personalities provide background information to the study and help us to understand the effects of varied intensities of plyometric training on motor fitness components and soccer techniques of junior players. The experts and research workers in the field of physical education are given primary importance in the present study.

2.1. STUDIES ON PLYOMETRICS TRAINING AND MOTOR FITNESS COMPONENTS

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

Diallo et al. (2001) conducted a study on the effects of plyometric training followed by a reduced training programme on physical performance in prepubescent soccer players. In adult population, stretch-shortening cycle exercise (plyometric exercise) is often used to improve leg muscle power and vertical jump performance. In children, limited information regarding this type of exercise is available. Twenty boys aged 12-13 years were divided in two groups (10 in each): jump group (JG) and control group (CG). JG trained 3 days/week during 10 weeks, and performed various plyometric exercises including jumping, hurdling and skipping. The subsequent reduced training period lasted 8 weeks. However, all subjects continued their soccer training. Maximal cycling power (Pmax) was calculated using a force-velocity cycling test. Jumping power was assessed by using the following tests: countermovement jump (CMJ), squat jump (SJ), drop jump (DJ), multiple 5 bounds (MB5) and repeated rebound jump for 15 seconds (RRJ15). Running velocities included: 20, 30 and 40 m (V20, V30, V40 m). Body fat percentage (BF percent) and lean leg volume were estimated by anthropometry. Before training, except for BF percent, all baseline anthropometric characteristics were similar between JG and CG. After the training programme, Pmax (p<0.01), CMJ (p<0.01), SJ (p<0.05), MB5 (p<0.01), RRJ15 (p<0.01) and V20 m (p<0.05), performances increased in the JG. During this period no significant performance
increase was obtained in the CG. After the 8-week of reduced training, except Pmax (p<0.05) for CG, any increase was observed in both groups. These results demonstrate that short-term plyometric training programmes increase athletic performances in prepubescent boys. These improvements were maintained after a period of reduced training.

Meylan et al. (2009) investigated the effects of in-season plyometric training within soccer practice on explosive actions of young players. In soccer, explosive actions such as jumping, sprinting, and changes of direction are essential to optimal performance not only in adults, but also in children's games. Fourteen children (13.3 +/- 0.6 years) were selected as the training group (TG) and 11 children (13.1 +/- 0.6 years) were defined as the control group (CG). All children were playing in the same league and trained twice per week for 90 minutes with the same soccer drills. The TG followed an 8-week plyometric program (i.e., jumping, hurdling, bouncing, skipping, and footwork) implemented as a substitute for some soccer drills to obtain the same session duration as CG. At baseline and after training, explosive actions were assessed with the following 6 tests: 10-meter sprint, agility test, 3 vertical jump tests (squat jump [SJ], countermovement jump [CMJ], contact test [CT] and multiple 5 bounds test [MB5]). Plyometric training was associated with significant decreases in 10-m sprint time (-2.1%) and agility test time (-9.6%) and significant increases in jump height for the CMJ (+7.9%) and CT (+10.9%). No significant changes in explosive actions after the 8-week period were recorded for the CG. The current study demonstrated that a
A short-term plyometric program within regular soccer practice improved explosive actions of young players compared to conventional soccer training only. Therefore, the short-term plyometric program had a beneficial impact on explosive actions, such as sprinting, change of direction, and jumping, which are important determinants of match-winning actions in soccer performance.

Ronnestad et al. (2008) compared the short-term effects of strength and plyometric training on sprint and jump performance 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. The 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.

**Thomas et al. (2009)** compared the effects of two plyometrics training techniques on power and agility in youth soccer players. Twelve males from a semiprofessional football club’s academy (age = 17.3 +/- 0.4 years, stature = 177.9 +/- 5.1 cm, mass = 68.7 +/- 5.6 kg) were randomly assigned to 6 weeks of depth jump (DJ) or countermovement jump (CMJ) training twice weekly. Participants in the DJ group performed drop jumps with instructions to minimize ground-contact time while maximizing height. Participants in the CMJ group performed jumps from a standing start position with instructions to gain maximum jump height. Post training, both groups experienced improvements in vertical jump height (p < 0.05) and agility time (p < 0.05) and no changes in sprint performance (p > 0.05). There were no differences between the treatment groups (p > 0.05). The study concludes that both DJ and CMJ plyometrics are worthwhile training activities for improving power and agility in youth soccer players.
Chelly et al. (2010) investigated the effects of in-season short-term plyometric training program on leg power, jump- and sprint performance of soccer players. The subjects (23 men, age 19 ± 0.7 years, body mass 70.5 ± 4.7 kg, height 1.75 ± 0.06 m, body fat 14.7 ± 2.6%) were randomly assigned to a control (normal training) group (Gc; n = 11) and an experimental group (Gex, n = 12) that also performed biweekly plyometric training. A force-velocity ergometer test determined PP. Characteristics of the squat jump (SJ) and the countermovement jump (CMJ) (jump height, maximal force and velocity before take-off, and average power) were determined by force platform. Video-camera kinematic analyses over a 40-m sprint yielded running velocities for the first step (VS), the first 5 m (V5m) and between 35 and 40 m (Vmax). Leg muscle volume was estimated using a standard anthropometric kit. Gex showed gains relative to controls in PP (p < 0.01); SJ (height p < 0.01; velocity p < 0.001), CMJ (height p < 0.001; velocity p < 0.001, average power p < 0.01) and all sprint velocities (p < 0.001 for V5m and Vmax, p < 0.01 for VS). There was also a significant increase (p < 0.05) in thigh muscle volume, but leg muscle volume and mean thigh cross-sectional area remain unchanged. We conclude that biweekly plyometric training of junior soccer players (including adapted hurdle and depth jumps) improved important components of athletic performance relative to standard in-season training. Accordingly, such exercises are highly recommended as part of an annual soccer training program.
McMillan et al. (2005) examined the physiological adaptations to soccer specific endurance training in professional youth soccer players. Improved oxygen uptake improves soccer performance as regards distance covered, involvements with the ball, and number of sprints. Large improvements in oxygen uptake have been shown using interval running. A similar physiological load arising from interval running could be obtained using the soccer ball in training. Eleven youth soccer players with a mean (SD) age of 16.9 (0.4) years performed high intensity aerobic interval training sessions twice per week for 10 weeks in addition to normal soccer training. The specific aerobic training consisted of four sets of 4 min work periods dribbling a soccer ball around a specially designed track at 90-95% of maximal heart frequency, with a 3 min recovery jog at 70% of maximal heart frequency between intervals. Mean VO2max improved significantly from 63.4 (5.6) to 69.8 (6.6) ml kg(-1) min(-1), or 183.3 (13.2) to 201.5 (16.2) ml kg(-0.75) min(-1) (p<0.001). Squat jump and counter movement jump height increased significantly from 37.7 (6.2) to 40.3 (6.1) cm and 52.0 (4.0) to 53.4 (4.2) cm, respectively (p<0.05). No significant changes in body mass, running economy, rate of force development, or 10 m sprint times occurred. Performing high intensity 4 min intervals dribbling a soccer ball around a specially designed track together with regular soccer training is effective for improving the VO2max of soccer players, with no negative interference effects on strength, jumping ability, and sprinting performance.
Sampaio et al. (2010) analyzed the short-term effects of complex and contrast training in soccer players' vertical jump, sprint, and agility abilities. This study compares the short-term effects of complex and contrast training (CCT) on vertical jump (squat and countermovement jump), sprint (5 and 15 m), and agility (505 Agility Test) abilities in soccer players. Twenty-three young elite Portuguese soccer players (age 17.4 +/- 0.6 years) were divided into 2 experimental groups (G1, n = 9, and G2, n = 8) and 1 control group (G3, n = 6). Groups G1 and G2 have done their regular soccer training along with a 6-week strength training program of CCT, with 1 and 2 training sessions .wk, respectively. G3 has been kept to their regular soccer training program. Each training session from the CCT program was organized in 3 stations in which a general exercise, a multiform exercise, and a specific exercise were performed. The load was increased by 5% from 1 repetition maximum each 2 weeks. Obtained results allowed identifying (a) a reduction in sprint times over 5 and 15 m (9.2 and 6.2% for G1 and 7.0 and 3.1%, for G2; p < 0.05) and () an increase on squat and jump (12.6% for G1 and 9.6% for G2; p < 0.05). The results suggested that the CCT induced the performance increase in 5 and 15 m sprint and in squat jump. Vertical jump and sprint performances after CCT program were not influenced by the number of CCT sessions per week (1 or 2 sessions./wk). From the obtained results, it was suggested that the CCT is an adequate training strategy to develop soccer players’ muscle power and speed.
**Gabbett et al. (2008)** conducted a study on the performance changes following training in junior rugby league players. The study investigated the time course of adaptations to training in young (i.e., <15 years) and older (i.e., <18 years) junior rugby league players. Fourteen young (14.1 +/- 0.2 years) and 21 older (16.9 +/- 0.3 years) junior rugby league players participated in a 10-week preseason strength, conditioning, and skills program that included 3 sessions each week. Subjects performed measurements of standard anthropometry (i.e., height, body mass, and sum of 7 skin folds), muscular power (i.e., vertical jump), speed (i.e., 10-m, 20-m, and 40-m sprint), agility (505 test), and estimated maximal aerobic power (i.e., multistage fitness test) before and after training. In addition, players underwent a smaller battery of fitness tests every 3 weeks to assess the time course of adaptation to the prescribed training stimulus. During the triweekly testing sessions, players completed assessments of upper-body (i.e., 60-second push-up, sit-up, and chin-up test) and lower-body (i.e., multiple-effort vertical jump test) muscular endurance. Improvements in maximal aerobic power and muscular endurance were observed in both the young and the older junior players following training. The improvements in speed, muscular power, maximal aerobic power, and upper-body muscular endurance were greatest in the young junior players, while improvements in lower-body muscular endurance were greatest in the older junior players. These findings demonstrate that young (i.e., <15 years) and older (i.e., <18 years) junior rugby league players adapt differently to a given training stimulus and that training programs should be modified to accommodate
differences in maturational and training age. In addition, the results of this study provide conditioning coaches with realistic performance improvements following 10-week preseason strength and conditioning program in junior rugby league players.

Brown et al. (2010) analyzed the oxygen consumption, heart rate, and blood lactate responses to an acute bout of plyometric depth jumps in college-aged men and women. Human Performance Laboratory, HPERLS Department, University of Nebraska at Kearney, Kearney, Nebraska, USA. Although plyometrics are widely used in athletic conditioning, the acute physiologic responses to plyometrics have not been described. Twenty recreationally trained college-aged subjects (10 men, 10 women) participated in a single session of 8 sets of 10 box depth jumps from a height of 0.8 m with 3 minutes of passive recovery between each set. Plyometric depth jumping elicited 82.5 +/- 3.1% and 77.8 +/- 3.1% of the measured maximal oxygen consumption (O2max) for women and men, respectively, with no difference in oxygen consumption in ml/kg/min or percent O2max between sexes or sets. Heart rate significantly increased (p < 0.05) from 68.1 +/- 2.9 beats x min-1 at rest to 169.6 +/- 1.2 beats x min-1 during depth jumping. Sets 5 to 8 elicited a higher (p < 0.05) heart rate (173.3 +/- 1.3 beats x min-1) than sets 1 to 4 (164.6 +/- 1.8 beats x min-1). Women exhibited a higher heart rate (p < 0.05) during sets 1 and 2 (169.9 +/- 2.8 beats x min-1) than men (150.7 +/- 4.4 beats x min-1). The blood lactate concentrations were significantly
(p < 0.05) increased above resting throughout all sets (1.0 +/- 0.2 mmolxL-1 compared with 2.9 +/- 0.1 mmolxL-1), with no differences between sexes or sets. Plyometric depth jumping significantly increased oxygen consumption, heart rate, and blood lactate in both men and women, but no significant difference was found between the sexes. Plyometric depth jumping from a height of 0.8 m has similar energy system requirements to what Wilmore and Costill termed "Aerobic Power" training, which should enhance O2max, lactate tolerance, oxidative enzymes, and lactate threshold.

**Newton et al. (2010)** experimented the influence of plyometric training on strength performance. 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 analyze 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 optimize 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 this 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 optimize strength gains.

Buchheit et al. (2010) compared the effects of explosive strength (Exp S) vs. repeated shuttle sprint (RS) training on repeated sprint ability (RSA) in young elite soccer players, 15 elite male adolescents (14.5 ± 0.5 years) performed, in addition to their soccer training program, RS (n = 7) or ExpS (n = 8) training once a week for a total of 10 weeks. RS training consisted of 2-3 sets of 5-6 × 15- to 20-m repeated shuttle sprints interspersed with 14 seconds of passive or 23 seconds of active recovery (≈2 m•s⁻¹); ExpS training consisted of 4-6 series of 4-6 exercises (e.g., maximal unilateral countermovement jumps (CMJs), calf and squat plyometric jumps, and short sprints). Before and after training, performance was assessed by 10 and 30 m (10 and 30 m) sprint times, best (RSAbest) and mean (RSAmean) times on a repeated shuttle sprint ability test, a CMJ, and a hopping (Hop) test. After training, except for 10 m (p = 0.22), all performances were
significantly improved in both groups (all p's < 0.05). Relative changes in 30 m (-2.1 ± 2.0%) were similar for both groups (p = 0.45). RS training induced greater improvement in RSA\textsubscript{best} (-2.90 ± 2.1 vs. -0.08 ± 3.3%, p = 0.04) and tended to enhance RSA\textsubscript{mean} more (-2.61 ± 2.8 vs. -0.75 ± 2.5%, p = 0.10, effect size [ES] = 0.70) than Exp\textsubscript{S}. In contrast, Exp\textsubscript{S} tended to induce greater improvements in CMJ (14.8 ± 7.7 vs. 6.8 ± 3.7%, p = 0.02) and Hop height (27.5 ± 19.2 vs. 13.5 ± 13.2%, p = 0.08, ES = 0.9) compared with RS. Improvements in the repeated shuttle sprint test were only observed after RS training, whereas CMJ height was only increased after Exp\textsubscript{S}. Because RS and Exp\textsubscript{S} were equally efficient at enhancing maximal sprinting speed, RS training-induced improvements in RSA were likely more related to progresses in the ability to change direction.

Avery et al. (2010) conducted a study on the effects of a short-term plyometric and resistance training program on fitness performance in boys age 12 to 15 years. This study 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 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. These 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.

Michael et al. (2006) assessed the effects of 6-week plyometric training program on agility. Subjects were divided into two groups, 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 F2, 26 = 25.42, p=0.0000 for the T-test agility measure. For the Illinois Agility test, a significant group effect F2, 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 F2, 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. The results of this study show that
plyometric training can be an effective training technique to improve an athlete’s agility.

Luebbers et al. (2003) experimented the effects of plyometric training and recovery on vertical jump performance and anaerobic power. This study examined the effects of 2 plyometric training programs, equalized for training volume, followed by a 4-week recovery period of no plyometric training on anaerobic power and vertical jump performance. Physically active, college-aged men were randomly assigned to either a 4-week ($n = 19$, weight $573.4 \pm 7.5$ kg) or a 7-week ($n = 19$, weight $580.1 \pm 12.5$ kg) program. Vertical jump height, vertical jump power, and anaerobic power via the Margaria staircase test were measured pre-training (PRE), immediately post-training (POST), and 4 weeks post-training (POST-4). Vertical jump height decreased in the 4-week group PRE (67.8 $\pm$ 7.9 cm) to POST (65.4 $\pm$ 7.8 cm). Vertical jump height increased from PRE to POST-4 in 4-week (67.8 $\pm$ 7.9 to 69.7 $\pm$ 7.6 cm) and 7-week (64.6 $\pm$ 6.2 to 67.2 $\pm$ 7.6 cm) training programs. Vertical jump power decreased in the 4-week group from PRE (8,660.0 $\pm$ 546.5 W) to POST (8,541.6 $\pm$ 557.4 W) with no change in the 7-week group. Vertical jump power increased PRE to POST-4 in 4-week (8,660.0 $\pm$ 546.5 W to 8,793.6 $\pm$ 541.4 W) and 7-week (8,702.8 $\pm$ 527.4 W to 8,931.5 $\pm$ 537.6 W) training programs. Anaerobic power improved in the 7-week group from PRE (1,121.9 $\pm$ 174.7 W) to POST (1,192.2 $\pm$ 189.1 W) but not the 4-week group. Anaerobic power significantly improved PRE to POST-4 in both groups. There were no significant differences between the 2 training groups. Four-week and 7-
week plyometric programs are equally effective for improving vertical jump height, vertical jump power, and anaerobic power when followed by a 4-week recovery period. However, a 4-week program may not be as effective as a 7-week program if the recovery period is not employed.

**Markovic (2007)** investigated the effect of plyometric training on vertical jump height. Meta-analyses of randomized and non-randomized 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 computerized 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 standardized units (i.e., effect sizes), the effect of PT on vertical jump height was 0.44 (95% CI 0.15 to 0.72), 0.88 (95% CI 0.64 to 1.11), 0.74 (95% CI 0.47 to 1.02) and 0.62 (95% CI 0.18 to 1.05) for the SJ, CMJ, CMJA and DJ, respectively. PT provides a statistically significant and practically relevant improvement in
vertical jump height with the mean effect ranging from 4.7% (SJ and DJ), over 7.5% (CMJA) to 8.7% (CMJ). These results justify the application of PT for the purpose of development of vertical jump performance in healthy individuals.

Rahim et al. (2005) examined the effects of plyometric, weight and plyometric-weight training on anaerobic power and muscular strength series. The study compared the effects of 3 different training protocols-plyometric training, weight training, and their combination on the vertical jump performance, anaerobic power and muscular strength. Based on their training, forty-eight male college students were divided into 4 groups: a plyometric training group (n=13), a weight training group (n=11), a plyometric plus weight training group (n=14), and a control group (n=10). The vertical jump, the fifty-yard run and maximal leg strength were measured before and after a six-week training period. Subjects in each of the training groups trained 2 days per week, whereas control subjects did not participate in any training activity. The data was analyzed by a 1-way analysis of variance (repeated measures design). The results showed that all the training treatments elicited significant (P<0.05) improvement in all of the tested variables. However, the combination training group showed signs of improvement in the vertical jump performance, the 50 yard dash, and leg strength that was significantly greater than the improvement in the other 2 training groups (plyometric training and weight training). This study provides support for the use
of a combination of traditional weight training and plyometric drills to improve the vertical jumping ability, explosive performance in general and leg strength.

Chelly et al. (2009) examined the effects of a back squat training program on leg power, jump, and sprint performances in junior soccer players. The study investigated the effects of voluntary maximal leg strength training on peak power output (Wpeak), vertical jump performance, and field performances in junior soccer players. Twenty-two male soccer players participated in this investigation and were divided into 2 groups: A resistance training group (RTG; age 17 +/- 0.3 years) and a control group (CG; age 17 +/- 0.5 years). Before and after the training sessions (twice a week for 2 months), Wpeak was determined by means of a cycling force-velocity test. Squat jump (SJ), countermovement jumps (CMJ), and 5-jump test (5-JT) performances were assessed. Kinematics analyses were made using a video camera during a 40-m sprint running test and the following running velocities were calculated: The first step after the start (V(first step)), the first 5 m (V(first 5 meters)), and between the 35 m and 40 m (V(max)). Back half squat exercises were performed to determine 1-repetition maximum (1-RM). Leg and thigh muscle volume and mean thigh cross-sectional area (CSA) were assessed by anthropometry. The resistance training group showed improvement in Wpeak (p < 0.05), jump performances (SJ, p < 0.05 and 5-JT, p < 0.001), 1-RM (p < 0.001) and all sprint running calculated velocities (p < 0.05 for both V(first step) and V(first 5 meters), p < 0.01 for V(max)). Both typical force-velocity relationships
and mechanical parabolic curves between power and velocity increased after the strength training program. Leg and thigh muscle volume and CSA of RTG remained unchanged after strength training. Back half squat exercises, including adapted heavy loads and only 2 training sessions per week, improved athletic performance in junior soccer players. These specific dynamic constant external resistance exercises are highly recommended as part of an annual training program for junior soccer players.

**Theodoros et al. (2000)** analysed the effects of two plyometric training programmes of different intensity on vertical jump performance in high school athletes. The present study compared the effect of intensity manipulation on a 6-week plyometric training programmes on vertical jump performance. Eighteen healthy adolescent male subjects were randomly allocated to periodized plyometric intensity (INCR), constant moderate plyometric intensity (CONS) and a control (CONT) group, for a 6-week plyometric training programme. Pre- and post-training measurements of net impulse, vertical take-off velocity, jump height and peak force were calculated from a countermovement jump. Contact time and flight time, rebound height and reactive strength index were calculated from a drop jump. INCR and CONS groups achieved improved vertical jump performance compared to CONT (P<0.05). Although there were no significant differences (P>0.05) between CONS and INCR for any of the performance variables, there was a trend for greater improvement for the INCR group. In
conclusion, manipulation of exercise intensity for short duration plyometric training could be less significant than the intervention itself. Longer training durations and density as well as consideration of specific plyometric exercises merit further investigation.

Arazi and Asadi (2011) examined the effect of aquatic and land plyometric training on strength, sprint, and balance in young basketball players. The study compared the effect of eight weeks of aquatic and land plyometric training on leg muscle strength, 36.5 and 60 meters sprint times, and dynamic balance test in young male basketball players. Eighteen young male basketball players (age=18.81±1.46 years, height=179.34±6.11 cm, body mass=67.80±9.52 kg, sport experience=4.8±2.47 years) volunteered in this study and divided to three groups; aquatic plyometric training (APT), land plyometric training (LPT) and control group (CON). Experimental groups trained; ankle jumps, speed marching, squat jumps, and skipping drills for eight weeks and 3 times a week for 40 min. The data were analyzed by one way analysis of variance with repeated measures, a Tukey post hoc testing and independent-sample t-test. The results showed there were not any significant differences between the APT and LPT groups in any of the variables tested (P>0.05). Significant increases were observed in post training both APT and LPT groups in 36.5-m and 60-m sprint times record compare to pre training (P<0.05). There was a significant difference in relative improvement between the APT and CON in 36.5-m, 60-m, and one repetition maximum leg
press (P<0.05). We conclude that plyometric training in water can be an effective technique to improve sprint and strength in young athletes.

Vescovi and Vanheest (2009) examined the effects of an anterior cruciate ligament injury prevention program on performance in adolescent female soccer players. Female soccer players are three times more likely to suffer a non-contact anterior cruciate ligament (ACL) tear compared with male soccer players. Several ACL injury prevention programs have been developed and are used to reduce injury risk. However, to date there is limited information on how such programs affect physical performance. The aim of this randomized controlled study was to investigate the effects of the Prevent Injury Enhance Performance (PEP) program in adolescent female soccer players. Four soccer teams were randomly assigned to an intervention (PEP) or control (CON) group and assessed at baseline, 6 weeks, and 12 weeks on linear sprinting, countermovement jump (CMJ), and two agility tests. A mixed model factorial ANOVA with repeated measures was used to assess for treatment effects on the dependent variables. Improvements in 27.3 and 36.6 m sprint times (<0.10 s) were evident during the first 6 weeks for PEP, but reverted back to baseline values by 12 weeks; there were no changes for 9.1 or 18.2 m sprint times in either group. There was no change in the CMJ height for PEP; however, there was a decrement at 6 and 12 weeks compared with baseline in CON. Performance on the Illinois and pro-agility tests declined in both groups. Our findings demonstrate that improvements in linear sprint performance were
small and transient in adolescent female soccer players, and that there was no benefit of the PEP program on CMJ or agility performance. ACL injury prevention programs designed as a structured warm-up routine seem to lack the necessary stimulus to enhance athletic performance.

Matavulj et al. (2001) examined the effects of plyometric training on jumping performance in junior basketball players. Three different training regimens were performed in order to study effects of plyometric training on elite junior basketball players. While control group (CG) participated only in the regular midseason training activity, another two groups performed a limited amount of plyometric training employing drop jumps from the height of either 50 cm (EG-50) or 100 cm (EG-100). The height of the maximal vertical jump (CMJ), as well as the maximal voluntary force (F) and the rate of force development (RFD) of hip and knee extensors were tested prior to and after the training. An increase in CMJ (4.8 and 5.6 cm in EG-50 and EG-100, respectively), as well as in F of hip extensors and RFD of knee extensors was observed in both experimental groups, while no significant changes were recorded in CG. When the pre-test scores were used as a covariate, both experimental groups demonstrated higher increase in CMJ and RFD of knee extensors than CG. However, no differences were observed between EG-50 and EG-100. The multiple correlation between four isometric parameters and CMJ revealed R²=0.29. A limited amount of plyometric training could improve jumping performance in elite junior basketball players and
this improvement could be partly related with an increase in F of hip extensors and RFD of knee extensors. However, neither of the two initial heights of the applied drop jumps proved to be more effective.

Impellizzeri et al. (2006) conducted a study on physiological and performance effects of generic versus specific aerobic training in soccer players. The study compared the effects of specific (small-sided games) vs. generic (running) aerobic interval training on physical fitness and objective measures of match performance in soccer. Forty junior players were randomly assigned to either generic (n = 20) or specific (n = 20) interval training consisting of 4 bouts of 4 min at 90 - 95% of maximum heart rate with 3 min active rest periods, completed twice a week. The following outcomes were measured at baseline (Pre), after 4 weeks of pre-season training (Mid), and after a further 8 weeks of training during the regular season (Post): maximum oxygen uptake, lactate threshold (Tlac), running economy at Tlac, a soccer-specific endurance test (Ekblom's circuit), and indices of physical performance during soccer matches (total distance and time spent standing, walking, and at low- and high-intensity running speed). Training load, as quantified by heart rate and rating of perceived exertion, was recorded during all training sessions and was similar between groups. There were significant improvements in aerobic fitness and match performance in both groups of soccer players, especially in response to the first 4 weeks of pre-season training. However, no significant differences between specific and generic aerobic interval
training were found in any of the measured variables including soccer specific tests. The results of this study showed that both small-sided games and running are equally effective modes of aerobic interval training in junior soccer players.

Jovanovic et al. (2008) analysed the effects of speed, agility, quickness training method on power performance in elite soccer players. The study evaluated the effects of the speed, agility, quickness (SAQ) training method on power performance in soccer players. Soccer players were assigned randomly to 2 groups: experimental group (EG; \( n = 50 \)) and control group (\( n = 50 \)). Power performance was assessed by a test of quickness-the 5-m sprint, a test of acceleration-the 10-m sprint, tests of maximal speed-the 20- and the 30-m sprint along with Bosco jump tests-squat jump, countermovement jump (CMJ), maximal CMJ, and continuous jumps performed with legs extended. The initial testing procedure took place at the beginning of the in-season period. The 8-week specific SAQ training program was implemented after which final testing took place. The results of the 2-way analysis of variance indicated that the EG improved significantly (\( p < 0.05 \)) in 5-m (1.43 vs. 1.39 seconds) and in 10-m (2.15 vs. 2.07 seconds) sprints, and they also improved their jumping performance in countermovement (44.04 vs. 4.48 cm) and continuous jumps (41.08 vs. 41.39 cm) performed with legs extended (\( p < 0.05 \)). The SAQ training program appears to be an effective way of improving some segments of power performance in young soccer players during the in-season period. Soccer coaches could use this
information in the process of planning in-season training. Without proper planning of the SAQ training, soccer players will most likely be confronted with decrease in power performance during in-season period.

Faigenbaum et al. (2009) conducted a study on "Plyo Play": a novel program of short bouts of moderate and high intensity exercise improves physical fitness in elementary school children. The present study examined the effects of a school-based plyometric training program (i.e., Plyo Play) on children's fitness performance. Forty children (8 to 11 yrs) participated in the program and 34 age-matched children served as controls. Performance of the long jump, sit and reach flexibility, abdominal curl, push-up, shuttle run, and half mile run was assessed at baseline and post-training. Children who participated in the program made significantly greater improvements than controls in the long jump (7.9 [+ or -] 17.3 cm vs. -0.3 [+ or -] 8.4 cm) pushup (4.1 [+ or -] 6.1 vs. 1.1 [+ or -] 5.2), and half mile run (-52.1 [+ or -] 68.7 sec. vs -10.5 [+ or -] 50.8 sec.). These data indicate that plyometric training can enhance selected measures of lower body power, upper body strength, and aerobic fitness in children.

Christou et al. (2006) studied the effects of resistance training on the physical capacities of adolescent soccer players. This study examined the effects of a progressive resistance training program in addition to soccer training on the physical capacities of male adolescents. Eighteen soccer players (age: 12-15 years) were separated in a soccer (SOC; n = 9) and a strength-soccer (STR; n = 9)
training group and 8 subjects of similar age constituted a control group. All players followed a soccer training program 5 times a week for the development of technical and tactical skills. In addition, the STR group followed a strength training program twice a week for 16 weeks. The program included 10 exercises, and at each exercise, 2-3 sets of 8-15 repetitions with a load 55-80% of 1 repetition maximum (1RM). Maximum strength ([1RM] leg press, bench-press), jumping ability (squat jump [SJ], countermovement jump [CMJ], repeated jumps for 30 seconds) running speed (30 m, 10 x 5-m shuttle run), flexibility (seat and reach), and soccer technique were measured at the beginning, after 8 weeks, and at the end of the training period. After 16 weeks of training, 1RM leg press, 10 x 5-m shuttle run speed, and performance in soccer technique were higher (p < 0.05) for the STR and the SOC groups than for the control group. One repetition maximum bench press and leg press, SJ and CMJ height, and 30-m speed were higher (p < 0.05) for the STR group compared with SOC and control groups. The above data show that soccer training alone improves more than normal growth maximum strength of the lower limbs and agility. The addition of resistance training, however, improves more maximal strength of the upper and the lower body, vertical jump height, and 30-m speed. Thus, the combination of soccer and resistance training could be used for an overall development of the physical capacities of young boys.
**Spurrs et al. (2003)** assessed the effects of plyometric training on distance running performance. This study examined whether changes in running performance resulting from plyometric training were related to alteration in lower leg muscular tendinous stiffness (MTS). Seventeen male runners were pre and post tested for lower leg MTS, maximum isometric force, rate of forced development, 5-pound distance test (5BT), Counter movement jump (CMJ) height, RE, Vo2 max, lactate threshold (Th la), and 3 – Km Time. Subjects were randomly split into an experimental (E) group, which completed 6 weeks of plyometrics training in conjunction with their normal running training, and a control (C) group, which trained as normal. Following training period, the E group significantly improved 3-Km performance (2.7%) and RE at each of the tested velocity, while no changes in vo2mac or Th (la) were recorded. CMJ height 5 BT, and MTS also increased significantly. No significant changes were observed any measures for the C group. The results clearly demonstrated that a 6 week plyometric programme led to improvements in 3-km running performance. It is postulated that the increase in MTS resulted improved RE. It is speculated that the improved Re led to Change in 3-Km running performance, as there were no corresponding alterations in vo2 max or Th(la).

**Chang et al. (2005)** studied the effect of plyometric training for lower extremities strength and power in high school female basketball players. Having targeted 16 girl basketball players in senior high school, a set of box horse
curriculum was designed with polymeric training for the study. The players were randomly divided into experimental groups (respectively with 30, 40 and 50 cm of box horse) and control group, four players for each group. Except for the control group, other three group had to receive 12 weeks of box horse training in addition to general basketball course training. The results of the study showed that either based on the plyometric training designed and applied to senior high school girl basketball players, CMJ or CJ has its effect.

Miller et al. (2006) studied the effects of a 6 week plyometric training program on agility. Subjects were divided into two groups; plyometric training and a control group. The plyometric training group performed 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 analyzed 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 F2, 26=25.42, p=0.0000 for the T-test agility measure. For the Illinois agility test, a significant group effect F2, 26=27.24, p=0.000 was also found. The plyometric training group had quicker post test times compared to the control group for the agility tests. A significant group effect F2,26=7.81. p=0.002 was found for the force plate test. The plyometric training group reduced time on the
ground on the post-test compared to the control group. The results of this study show that plyometric training can be an effective training technique to improve an athlete’s agility.

2.2. STUDIES ON PLYOMETRICS TRAINING AND SOCCER TECHNIQUES

Cervantes (2011) conducted a study on the effects of plyometric training on explosive strength, acceleration capacity and kicking speed in young elite soccer players. Twenty-two players participated in the study: control group (CG), (N.=11; 18.2 ± 0.9 years) and treatment group (TG) (N.=11; 18.4 ± 1.1 years). Both groups performed technical and tactical training exercises and matches together. However, the CG players followed the regular physical conditioning program, which was replaced by a plyometric program for TG. Ten weeks plyometric training took place three days a week and included jumps over hurdles, horizontal jumps and lateral jumps over hurdles. Jumping ability, 10 m sprint and kicking speed were measured on five separate occasions. Two-way analysis of variance (ANOVA) with repeated measures reflected that the TG demonstrated significant increases (P<0.05) in jumping ability and acceleration capacity after six weeks of training and in kicking speed with dominant and non-dominant leg after eight and ten weeks respectively. On the other hand there were no significant changes in CG players throughout the study. The main findings revealed that a 10-week plyometric program may be an effective training stimulus to improve explosive strength compared to a more conventional physical training
program. The improvements in explosive strength can be transferred to acceleration capacity and kicking speed but players need time to transfer these increases.

Mujika et al. (2009) postulated the effect of short-term sprint and power training programs on elite junior soccer players. This study examined the effects of 2 in-season short-term sprint and power training protocols on vertical countermovement jump height (with or without arms), sprint (Sprint-15m) speed, and agility (Agility-15m) speed in male elite junior soccer players. Twenty highly trained soccer players (age 18.3 +/- 0.6 years, height 177 +/- 4 cm, body mass 71.4 +/- 6.9 kg, sum skinfolds 48.1 +/- 11.4 mm), members of a professional soccer academy, were randomly allocated to either a Contrast (n = 10) or sprint (n = 10) group. The training intervention consisted of 6 supervised training sessions over 7 weeks, targeting the improvement of the players' speed and power. Contrast protocol consisted of alternating heavy-light resistance (15-50% body mass) with soccer-specific drills (small-sided games or technical skills). Sprint training protocol used line 30-m sprints (2-4 sets of 4 x 30 m with 180 and 90 seconds of recovery, respectively). At baseline no difference between physical test performances was evident between the 2 groups (p > 0.05). No time x training group effect was found for any of the vertical jump and Agility-15m variables (p > 0.05). A time x training group effect was found for Sprint-15m performance with the CONTRAST group showing significantly better scores than the sprint group
(7.23 +/- 0.18 vs. 7.09 +/- 0.20, p < 0.01). In light of these findings contrast training should be preferred to line sprint training in the short term in young elite soccer players when the aim is to improve soccer-specific sprint performance (15 m) during the competitive season.

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

_Campo et al. (2009)_ reported the effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. This study examined how 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 this 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. It is 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.

Chelly et al. (2010) analyzed the relationships of peak leg power, 1 maximal repetition half back squat, and leg muscle volume to 5-m sprint performance of junior soccer players. Performance over very short distances (1-5 m) is important in soccer. The study investigated this in 23 male regional-level soccer players aged 17.2 +/- 0.7 years, filming body markers to determine the average velocity and acceleration over the first step (V(S) and A(S)) and the first 5 m (V(5), A(5)). Data were related to scores on a force-velocity test, squat jump (SJ), countermovement jump (CMJ), and 1 maximal repetition (1 RM) half back squat. Leg and thigh muscle volumes were also assessed anthropometrically. V(5) was positively correlated with leg and thigh muscle volumes (r = 0.61, p < 0.05; r = 0.43, p < 0.05, respectively), SJ power (absolute and relative to body mass, r = 0.45, p < 0.05; r = 0.43, p < 0.05, respectively), absolute force-velocity leg power (r = 0.49, p < 0.05), and 1 RM half back squat (r = 0.66, p < 0.001). The use of dimensional exponents did not change coefficients materially. V(S) was also correlated with leg muscle volume and 1 RM back half squat (r = 0.56, p < 0.01; r
and more weakly with force-velocity leg power and SJ force ($r = 0.49, p < 0.05; r = 0.46, p < 0.5$, respectively). However, the CMJ was unrelated to velocity or acceleration. Sprinting ability is correlated with measures of power and force such as the force-velocity test, SJ, and 1 RM half back squat; such measures thus offer useful guidance to soccer coaches who wish to improve the short-distance velocity of their players.

Moore et al. (2005) compared two twelve week off-season combined training programs on entry level collegiate soccer players’ performance. Olympic-style lifts (OSL) and plyometric exercises (PE) are frequently combined with traditional resistance training (TRT) to improve athletic performance. This study directly compared the performance effect of TRT (30 minutes) combined with either OSL or no depth-jump PE (15 minutes) on entry level competitive collegiate athletes. Ten female and 5 male competitive soccer players, divided into 2 groups, completed 12 weeks of tri-weekly training during their off-season. Countermovement vertical jump, 4 repetition maximum squat, 25-m sprint, and figure-8 drill on a 5-dot mat were conducted pre-, mid-, and post intervention. Significant improvements were made by both groups in each performance parameter over the 12-week period ($p < 0.05$), with no significant differences found between the training groups. Although these training modalities may achieve their results through slightly different mechanisms, the performance-related improvements may not be significantly different for entry-level collegiate athletes with little resistance training experience.
Shallaby (2010) analysed the effect of plyometric exercises use on the physical and skillful performance of basketball players. This study identified the effectiveness of plyometric exercises on the special physical abilities and skillful performance of basketball players. It was applied to a sample of 20 players of 16 years old from El-Shoban El-Muslimin club in Port Said. They 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 at 120 minutes for each unit. Through the training unit, the exercises were united between the two groups except for the part of the special physical preparation. 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%).
Vescovi et al. (2008) assessed the physical performance characteristics of high-level female soccer players 12-21 years of age. This study described the physical performance characteristics of female soccer players ranging in age from 12 to 21 years. High-level female soccer players (n=414) were evaluated on linear sprinting (36.6 m with 9.1 m splits), countermovement jump (CMJ), and two agility tests. Separate one-way ANOVAs were used to compare performance characteristics between (1) each year of chronological age and (2) three age groups: 12-13 years, n=78, 14-17 years, n=223, and 18-21 years, n=113. Mean linear sprint speed over 9.1 m was similar across all chronological ages, however sprint speed over the final 9.1 m, CMJ height and agility scores improved until approximately 15-16 years. Outcomes from the group data indicated better performance on all tests for the 14-17-year-old group compared with the 12-13-year-old group. Additionally, sprint speed on the second and fourth 9.1 m splits and 36.6 m sprint speed as well as performance on the Illinois agility test was better in the 18-21-year-old group compared with the 14-17-year-old group. The findings from this study indicate that marked improvements of high intensity short duration work occur up until 15-16 years. Smaller gains in performance were observed beyond 16 years of age as evidenced by better performance on 36.6 m sprint speed, several sprint splits and the Illinois agility test in the college aged players (i.e., 18-21-year-old group).
Shaji et al. (2009) analysed and compared the plyometric training program and dynamic stretching on vertical jump and agility in male collegiate basketball player. The subjects included 45, healthy male collegiate basketball players between the ages of 18-25. All subjects were tested in the vertical jump and agility using the Sergeant Jump test and T-test respectively prior to starting the dynamic stretching and plyometric training program. The subjects then completed a four week plyometric training program and were retested. Univariate ANOVA was conducted to analyze the change scores (post – pre) in the independent variables by group (plyometric, dynamic stretching and combined) with pre scores as covariates. The Univariate ANOVA revealed a significant group effect for Sergeant Jump test $F = 12.95, P = 0.000$ for Dynamic stretching group, $F = 12.55, P = 0.000$ for Plyometric training group and $F = 15.11, P = 0.000$ for combined group. The combined group revealed, maximum increase in the height when compared with the pretest scores. For the T Test agility scores a significant group effect was found $F = 2.00, P = 0.043$ for Plyometric training group, $F = 9.14, P = 0.000$ for combined group while dynamic stretching group $F = 2.11, P = 0.088$ revealed non significant results. The findings suggested that two days of plyometric training a week in combination with dynamic stretching for four weeks is sufficient enough to show improvements in vertical jump height and agility. The results also suggest that two days of plyometric training and dynamic stretching are equally effective in improving vertical jump height. In contrast dynamic
stretching two days a week for four weeks was not sufficient enough to show improvements in agility while plyometric training was sufficient.

Kotzamanidis et al. (2006) analysed the effect of plyometric training on running performance and vertical jumping in prepubertal boys. This study investigated the effect of plyometric training on running velocity (RV) and squat jump (SJ) in prepubescent boys. Fifteen boys (11.1 +/- 0.5 years) followed a 10-week plyometric program (JUMP group). Another group of 15 boys (10.9 +/- 0.7 years) followed only the physical education program in primary school and was used as the control group (CONT group). Running distances (0-10 m, 10-20 m, 20-30 m, and 0-30 m), were selected as testing variables to evaluate the training program. The total number of jumps was initially 60 per session, which was gradually increased over a period of 10 weeks to 100 per session. Results revealed significant differences between CONT and JUMP groups in RV and SJ. In JUMP group the velocity for the running distances 0-30, 10-20, and 20-30 m increased (p < 0.05), but not for the distance 0-10 m (p > 0.05). Additionally, the SJ performance of the JUMP group increased significantly, as well (p < 0.05). There was no change in either RV or SJ for the CONT group. These results indicate that plyometric exercises can improve SJ and RV in prepubertal boys. More specifically, this program selectively influenced the maximum velocity phase, but not the acceleration phase.
Mili et al. (2008) conducted a study on the effect of plyometric training on the explosive Strength of leg muscles of volleyball players on single foot and two-foot takeoff jumps. The effects of a six-week plyometric training program during the second half of the preliminary period of the annual training cycle was studied. The sample consisted of 46 subjects aged 16 (± 6 months). The experimental group consisted of 23 volleyball players, with an average height of 186.35 ± 8.52 and average weight of 70.57 ± 8.98. The control group consisted of 23 high school students, with an average height of 177.35 ± 4.80 and body weight of 68.91 ± 6.48, who had not been exposed to the plyometric method as part of their physical education classes. The sample of measuring instruments consisted of eight tests of explosive leg strength: the two-foot takeoff block jump, the right foot takeoff block jump, the left foot takeoff block jump, the two-foot takeoff, spike jump, the right foot takeoff spike jump, the left foot takeoff spike jump, the standing depth jump and the standing triple jump. Using a multivariate and univariate statistical method, we were able to determine a statistically significant difference in explosive strength in favor of the experimental group. We determined an increase in explosive strength for the two-foot and single foot takeoff jumps.

Gomez et al. (2008) speculated the effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. The effects of a training program consisting of weight lifting combined with plyometric exercises on
kicking performance, myosin heavy-chain composition (vastus lateralis), physical fitness, and body composition (using dual-energy X-ray absorptiometry (DXA)) was examined in 37 male physical education students divided randomly into a training group (TG: 16 subjects) and a control group (CG: 21 subjects). The TG followed 6 weeks of combined weight lifting and plyometric exercises. In all subjects, tests were performed to measure their maximal angular speed of the knee during instep kicks on a stationary ball. Additional tests for muscle power (vertical jump), running speed (30 m running test), anaerobic capacity (Wingate and 300 m running tests), and aerobic power (20 m shuttle run tests) were also performed. Training resulted in muscle hypertrophy (+4.3%), increased peak angular velocity of the knee during kicking (+13.6%), increased percentage of myosin heavy-chain (MHC) type IIa (+8.4%), increased 1 repetition maximum (1 RM) of inclined leg press (ILP) (+61.4%), leg extension (LE) (+20.2%), leg curl (+15.9%), and half squat (HQ) (+45.1%), and enhanced performance in vertical jump (all \( p \leq 0.05 \)). In contrast, MHC type I was reduced (−5.2%, \( p \leq 0.05 \)) after training. In the control group, these variables remained unchanged. In conclusion, 6 weeks of strength training combining weight lifting and plyometric exercises results in significant improvement of kicking performance, as well as other physical capacities related to success in football (soccer).

Sankey et al. (2008) reported the results of the effects of two plyometric training programmes of different intensity on vertical jump performance in high school athletes. This study compared the effect of intensity manipulation on a 6-
week plyometric training programmes on vertical jump performance. Eighteen healthy adolescent male subjects were randomly allocated to periodized plyometric intensity (INCR), constant moderate plyometric intensity (CONS) and a control (CONT) group, for a 6-week plyometric training programme. Pre- and post-training measurements of net impulse, vertical take-off velocity, jump height and peak force were calculated from a countermovement jump. Contact time and flight time, rebound height and reactive strength index were calculated from a drop jump. INCR and CONS groups achieved improved vertical jump performance compared to CONT (P<0.05). Although there were no significant differences (P>0.05) between CONS and INCR for any of the performance variables, there was a trend for greater improvement for the INCR group. In conclusion, manipulation of exercise intensity for short duration plyometric training could be less significant than the intervention itself. Longer training durations and density as well as consideration of specific plyometric exercises merit further investigation.

Andrew et al. (2008) assessed the effects of three modified plyometric depth jumps and periodized weight training on lower extremity power. This study compared the effects of modified depth jump plyometric exercises versus a periodized weight training program on the following functional tests: one-legged vertical jump, two-legged vertical jump, 30-meter sprint, standing broad jump, and 1 rm of the seated single leg press. Sixty-four untrained participants (18-28yr) were randomly assigned to one of the following groups: hip depth jump (n = 12),
knee depth jump (n = 13), ankle depth jump (n = 13), weight training (n = 13), or a control (n = 13). Experimental groups trained two days a week for 12 weeks. Statistically significant improvements were observed among the plyometric groups for functional tests of power and the weight training group for functional tests of strength and speed. Results indicate that modified plyometric depth jumps offer a greater degree of specificity related to power training in athletes.

Santos et al. (2011) postulated the effects of plyometric training followed by detraining and reduced training periods on explosive strength in adolescent male basketball players. This study determined the effects of (a) plyometric training on explosive strength indicators in adolescent male basketball players and (b) detraining and reduced training on previously achieved explosive strength gains. Two groups were formed: an experimental and a control group. The former was submitted to a 10-week in-season plyometric training program, twice weekly, along with regular basketball practice. Simultaneously, the control group participated in regular basketball practice only. At the end of this period, the experimental group was subdivided into 2 groups: a reduced training group and a detraining group. All participants were assessed on squat jump, countermovement jump, Abalakov test, depth jump, mechanical power, and medicine ball throw at the beginning and at the end of the 10-week in-season plyometric training and on weeks 4, 8, 12, and 16 of the in-season detraining and reduced training periods. In the first phase of the study, the experimental group significantly increased all the
assessed indicators \((p < 0.05)\). In the following phase and in general all the groups maintained the previously achieved results. In conclusion, plyometric training showed positive effects on upper- and lower-body explosive strength in adolescent male basketball players. Moreover, we can state that both detraining and a reduced training program indistinctly contribute to maintenance of strength levels. These results highlight the unique power that basketball-specific training seems to have on the sustainability and maintenance of sport performance.

Masamoto et al. (2003) investigated the effects of plyometric exercise on maximum squat performance in male athletes. This study examined the acute effects of plyometric exercise on 1 repetition maximum (IRM) squat performance in trained male athletes. Twelve men (mean age \(6 \text{ SD}: 20.5 \pm 1.4\) years) volunteered to participate in 3 testing sessions separated by at least 6 days of rest. During each testing session the 1RM was assessed on back squat exercise. Before all 3 trials subjects warmed up on a stationary cycle for 5 minutes and performed static stretching. Subjects then performed 5 sub maximal sets of 1–8 repetitions before attempting a 1RM lift. Subjects rested for at least 4 minutes between 1RM trials. During the first testing session (T1) subjects performed a series of sets with increasing load until their 1RM was determined. During the second and third testing sessions subjects performed in counterbalanced order either 3 double-leg tuck jumps (TJ) or 2 depth jumps (DJ) 30 seconds before each 1RM attempt. The average 1RM lifts after T1 and testing sessions with TJ or DJ were 139.6 \(\pm 29.3\)
kg, 140.5 ± 25.6 kg, and 144.5 ± 30.2 kg, respectively (T1, DJ; p < 0.05). These data suggest that DJ performed before 1RM testing may enhance squat performance in trained male athletes.

Alves et al. (2010) analysed the short-term effects of complex and contrast training in soccer players’ vertical jump, sprint, and agility abilities. This study analyzed the short-term effects of complex and contrast training (CCT) on vertical jump (squat and countermovement jump), sprint (5 and 15 m), and agility (505 Agility Test) abilities in soccer players. Twenty-three young elite Portuguese soccer players (age 17.4 ± 0.6 years) were divided into 2 experimental groups (G1, n = 9, and G2, n = 8) and 1 control group (G3, n = 6). Groups G1 and G2 have done their regular soccer training along with a 6-week strength training program of CCT, with 1 and 2 training sessions wk, respectively. G3 has been kept to their regular soccer training program. Each training session from the CCT program was organized in 3 stations in which a general exercise, a multiform exercise, and a specific exercise were performed. The load was increased by 5% from 1 repetition maximum each 2 weeks. Obtained results allowed identifying (a) a reduction in sprint times over 5 and 15 m (9.2 and 6.2% for G1 and 7.0 and 3.1%, for G2; p < 0.05) and () an increase on squat and jump (12.6% for G1 and 9.6% for G2; p < 0.05). The results suggested that the CCT induced the performance increase in 5 and 15 m sprint and in squat jump. Vertical jump and sprint performances after CCT program were not influenced by the number of
CCT sessions per week (1 or 2 sessions/wk). From the obtained results, it was suggested that the CCT is an adequate training strategy to develop soccer players' muscle power and speed.

Polman et al. (2004) identified the effective conditioning of female soccer players. We compared the efficacy of three physical conditioning programmes provided over a 12 week period (24 h in total) on selected anthropometric and physical fitness parameters in female soccer players. Two of the groups received physical conditioning training in accordance with speed, agility and quickness (SAQ); one group used specialized resistance and speed development SAQ equipment (equipment group; n = 12), while the other group used traditional soccer coaching equipment (non-equipment group; n = 12). A third group received their regular fitness sessions (active control group; n = 12). All three interventions decreased (P < 0.001) the participants' body mass index (-3.7%) and fat percentage (-1.7%), and increased their flexibility (+14.7%) and maximal aerobic capacity (VO2max) (+18.4%). The participants in the equipment and non-equipment conditioning groups showed significantly (P < 0.005) greater benefits from their training programme than those in the active control group by performing significantly better on the sprint to fatigue (-11.6% for both the equipment and non-equipment groups versus -6.2% for the active control group), 25 m sprint (-4.4% vs. -0.7%), left (-4.5% vs. -1.0%) and right (-4.0% vs. -1.4%) side agility, and vertical (+18.5% vs. +4.8%) and horizontal (+7.7% vs. +1.6%) power tests.
Some of these differences in improvements in physical fitness between the equipment and non-equipment conditioning groups on the one hand and the active control group on the other hand were probably due to the specificity of the training programmes. It was concluded that SAQ training principles appear to be effective in the physical conditioning of female soccer players. Moreover, these principles can be implemented during whole team training sessions without the need for specialized SAQ equipment. Finally, more research is required to establish the relationship between physical fitness and soccer performance as well as the principles underlying the improvements seen through the implementation of SAQ training programmes.

Markovic et al. (2007) investigated the effects of sprint and plyometric training on muscle function and athletic performance. This study 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 countermovement 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 (approximately 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.

We conclude that short-term sprint training produces similar or even greater training effects in muscle function and athletic performance than does conventional plyometric training. This study provides support for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

Kotzamanidis et al. (2005) assessed the effect of a combined high-intensity strength and speed training program on the running and jumping ability of soccer players. This study investigated the effect of a combined heavy-resistance and running-speed training program performed in the same training session on strength, running velocity (RV), and vertical-jump performance (VJ) of soccer players. Thirty-five individuals were divided into 3 groups. The first group (n = 12, COM group) performed a combined resistance and speed training program at the same training session, and the second one (n = 11, STR group)
performed the same resistance training without speed training. The third group was the control group (n = 12, CON group). Three jump tests were used for the evaluation of vertical jump performance: squat jump, countermovement jump, and drop jump. The 30-m dash and 1 repetition maximum (1RM) tests were used for running speed and strength evaluation, respectively. After training, both experimental groups significantly improved their 1RM of all tested exercises. Furthermore, the COM group performed significantly better than the STR and the CON groups in the 30-m dash, squat jump, and countermovement jump. It is concluded that the combined resistance and running-speed program provides better results than the conventional resistance training, regarding the power performance of soccer players.

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

**Skurvydas et al. (2010)** evaluated the effect of plyometric training on central and peripheral fatigue in boys. This study investigated the effect of high-intensity plyometric training (PT) on central and peripheral fatigue during exercise performed at maximal intensity in prepubertal boys. The boys (n=13, age 10.3±0.3 years) performed continuous 2-min maximal voluntary contractions (MVC) before and after 16 high-intensity PT sessions (two training sessions per week, 30 jumps in each session, 20 s between jumps). The greatest effect of PT was on excitation-contraction coupling: twitch force increased by 323.2±210.8% and the height of a counter-movement jump increased by 36.7±11.7%, whereas quadriceps femoris (QF) muscle voluntary activation index, central activation ratio and MVC did not change significantly after PT. The thickness of QF increased by 8.8±7.9% after
PT. Central fatigue increased significantly by about 15-20% after PT, whereas peripheral fatigue decreased significantly by about 10% during the 2-min MVC. Central fatigue and peripheral fatigue during the 2-min MVC were inversely related before PT, but this relationship disappeared after PT.

Impelizzeri et al. (2008) report the effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. This study compared the effects of plyometric on sand versus a grass surface on muscle soreness, vertical jump height and sprinting ability. Design of the study was parallel tow group, randomized longitudinal (pre-test – post test) study. After random allocation 18 soccer players completed 4 weeks of plyometric training on grass (grass group) and 19 players on san (sand group). Before and after plyometric training, 10m and 20m sprit time, squat jump (SJ), countermovement jump (CMJ) and eccentric utilization ratio (CMJ/SJ) were determined. Muscle soreness was measured using a Liket scale. No training surface x time interaction were found for sprint time (p>0.87), whereas a trend was found SJ (P=0.08), with both groups showing similar improvements (p<0.001). On the other hand, the grass group improved their CMJ (p=0.033) and CMJ/SJ (p=0.005) significantly (p<0.001) more than players in the sand group. In contrast, players in the sand group experienced less muscle soreness than those in the grass group (p<0.001). Plyometric training on sand improved both jumping spiriting ability and induced less muscle soreness. A grass surface seems to be
superior in enhancing CMJ performance while the sand surface showed a greater improvement in SJ. Therefore, plyometric training on different surfaces may be associated with different training-induced effects on some neuromuscular factors related to efficiency of the stretch-shorting cycle.

Manolopoulos et al. (2006) reported the effects of combined strength and kick coordination training on soccer kick biomechanics in amateur players. This study examined the effect of a soccer (strength and technique) training program on kinematics and electromyography (EMG) muscle activity during an instep kick. Ten amateur soccer players (aged 19.9 ±0.4 years, body mass 74.8±9.1kg, height 177.4±6.7cm) constituted the experimental group (EG) whereas 10 players (age 21.6±1.3 years, weight 71.5±6.7 kg, height 175.2±3.4 cm) served as controls. The EG followed a 10 week soccer specific training programme comparing strength and technique exercises. All participants performed an instep cocker kink using a two- step approach while three-dimensional data and EMG from six muscles of swinging and support legs were recorded prior to and after training. Maximum isometric leg press strength, 10-m sprit performance and maximum support performance a bicycle ergometer were also measured. Analysis of variance designs with repeated measured showed that the EG improved significantly (p<0.05) maximum ball speed, the linear velocity of the foot, ankle and angular velocity of all joints during the final phase of the kick. Training had insignificant effects on EMG values apart from an increase in the averaged EMG of the vastest
medialis whereas maximum isometric strength and sprint times significantly improved after training (p<0.05). The present results suggest that application of the training programs using soccer specific strength exercises would be particularly effective in improving of soccer kick performance.

**Kotzamanidis (2006)** explored the effect of plyometric training on running performance and vertical jumping in pre-pubertal boys. This study investigated the effect of plyometric training on running velocity (RV) and squat jump (SJ) in prepubescent boys. Fifteen boys (11.1 ± 0.5 years) followed a 10-week plyometric training (JUMP group). Another group of 15 boys (10.9 ± 0.7 years) followed only the physical education programme in primary school and was used as the control group (CONT group). Running distances (0-10 m, 10-20 m, 20-30 m, and 0-30 m) were selected as testing variables to evaluate the training program. The total number of jumps was initially 60 per session, which was gradually increased over a period of 10 weeks to 100 per session. Results revealed significant differences between CONT and JUMP groups in RV and SJ. In JUMP group the velocity for the running distances 0-30, 10-20, and 20-30 m increased (p<0.05), but not for the distance 0-10 m (p>0.05). Additionally, the SJ performance of the JUMP group increased significantly, as well (p<0.05). There was no change in either RV or SJ for the CONT group. These results indicate that plyometric exercises can improve SJ and RV in pre-pubertal boys. More specifically, this program selectively influence the maximum velocity phase, but not the acceleration phase.
2.3. SUMMARY OF REVIEW OF LITERATURE

The reviews are presented under two sections namely studies on plyometric training and motor fitness components (n=29) and studies on plyometric training and soccer techniques (n=25). All the research studies that are presented in this section prove that varied intensities of plyometric training contribute significantly for better improvement in selected motor fitness components and soccer techniques.

Research studies using plyometric training revealed compatible results (Izquierdo et al. 2008, Meylan et al. 2009, Campo et al. 2009, Manolopoulos et al. 2006, Miller et al. 2006 and Spurrs et al. 2003). There was clear evidence that the use of plyometric training was one of the effective training methods to improve the selected motor fitness components among the junior soccer players.

The studies suggested that plyometric training has been found to elicit greater changes in selected soccer techniques (Cervantes et al. 2011, Rubley et al. 2011, Shallaby et al. 2010, Gomez et al. 2008, Chelly et al. 2010, Michael et al. 2006 and Kotsamanidis et al. 2006).

The review of literature helped the researcher from the methodological point of view too. It was learnt that most of the research studies cited in this chapter on analysis and experimental design were appropriate. The present study may serve as a foundation and main ingredient for future research to investigate the proper training methods for changing the motor fitness components and soccer techniques of junior players.