CHAPTER II

REVIEW OF RELATED LITERATURE
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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 various sports specific training methods of strength training, plyometric training, skill movement training and their combinations on range of motion, physical, physiological, psychological and performance related variables. The experts and research workers in the field of physical education are of primary importance to the present study.

2.1 STUDIES ON STRENGTH TRAINING

Ken Jones et al. (1999) conducted a study on effects of compensatory acceleration on upper-body strength and power in collegiate football players. The purpose of this study was to compare the effects of maximum concentric acceleration training versus traditional upper-body training on the development of strength and power of collegiate NCAA Division IAA football players. Power was tested with a seated medicine ball throw (n = 30) and a force platform plyometric push-up test (n = 24). Upper-body strength was tested by using a bench press with 1 repetition maximum
All players were on an identical off-season weight-training program. The control group performed exercises with conventional concentric velocity and the experimental group performed the concentric phase of each repetition as rapidly as possible. Two-way repeated-measures analysis of variance was used to determine training and group differences. Significant training effects for all strength and power measures indicated that both groups increased strength and power. Significant training by group interaction indicates the experimental group increased significantly more than the control group in the bench press and throw. Significance was not reached for any of the training by group interactions for force platform variables. The results of this study support the use of maximal acceleration of concentric contractions by collegiate football players during upper-body strength and power training.

Mangine GT et al. (2008) conducted a study on combined ballistic and heavy resistance training on maximal lower- and upper-body strength in recreationally trained men. The purpose of the present study was to investigate 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 3 days per 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. Non significant 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 differences observed between groups. The results of this study support the inclusion of ballistic exercises in a heavy resistance training program for increasing 1RM bench press and enhancing lower-body power.

*Calder et al. (1996)* conducted a study on comparison of whole and split weight training routines in young women. Young women were subjected to three weight training regimes: (a) a whole routine (W) which did four upper (five sets of 6-10 RM) and three lower body (five sets 10-12 RM) weight training exercises in two single sessions per week, (b) a split session routine (S) which did the upper body exercises two days a week and the lower body exercises on two other days of the week, and (c) a control group which did no training. Both W and S groups changed similarly over 20 weeks of training in terms of 1 RM, arm curl, bench press, and leg press. Both groups improved the arm and trunk lean mass similarly but only W increased in leg lean mass. Whole-body lean tissue mass increased and whole-body percent fat decreased with training in both groups. Young untrained women respond to weight training in terms of strength increase and lean body mass changes irrespective of the exercise training schedule.
Paula et al. (1998) assessed whether resistance training modified the changes in joint range of motion developed through flexibility training. Young adult Ss (M = 26; F = 15) were allocated to one of four groups: i) resistance training, ii) flexibility training, iii) resistance and flexibility training, and iv) no training. There was no change in either muscle strength or flexibility in the control group. Muscle strength improved in both resistance-training groups. Flexibility improved in both flexibility training groups but it was unchanged in the resistance training group. Resistance training did not affect gains developed through flexibility training.

Stretch and Gray (1998) stated that the fast-bowlers have not traditionally participated in much resistance training. A major concern has always been that strength training would reduce flexibility and speed. To the contrary, a sensible strengthening programme can enhance an individual's technique and performance. Strengthening may also correct or prevent a muscle imbalance and thus reduce the incidence of injury. A joint which is supported by strengthened muscles is far better equipped to resist many of the impact forces experienced during bowling. Strength training for the fast-bowler consists of a series of exercises performed with light weights, theraband or body weight. The exercises should be performed in high repetitions with short rest periods in order to enhance muscular endurance. Young schoolboys should start with body weight exercises and progress through theraband exercises to weight-training. Weight training should be initiated under supervision. Incorrect use of weights such as incorrect body position, uncontrolled movement or using weights which are too heavy, place the fast-bowler at considerable risk for injury. Gym machines are not as effective as body weight, theraband or free weight exercises in that they are limited to movement in one direction. The fast
bowling action requires simultaneous movement in all three planes, which can be achieved using these three forms of exercise.

Miranda H. et al. (2009) conducted a study on the effect of rest interval length on the volume completed during upper body resistance exercise. The purpose of the current study was to compare the workout volume (sets x resistance x repetitions per set) completed during two upper body resistance exercise sessions that incorporated 1 minute versus 3 minute rest intervals between sets and exercises. Twelve trained men completed two experimental sessions that consisted of 5 upper body exercises (i.e. barbell bench press, incline barbell bench press, pec deck flye, barbell lying triceps extension, triceps pushdown) performed for three sets with an 8-RM load. The two experimental sessions differed only in the length of the rest interval between sets and exercises; one session with a 1-minute and the other session with a 3-minute rest interval. The results demonstrated that for each exercise, significantly greater workout volume was completed when resting 3 minutes between sets and exercises (p < 0.05). These results indicate that during a resistance exercise session, if sufficient time is available, resting 3 minutes between sets and exercises allows greater workout volume for the upper body exercises examined.

Calpenter DM et al. (1991) conducted a study to evaluate the Effect of 12 and 20 weeks of resistance training on lumbar extension torque production. This study compared the effects of varied training frequencies on the development of isometric lumbar extension torque (strength) over 12- and 20-week training periods. First-six subjects were randomly assigned to training once every other week (training group 1, n = 10), once per week (training group 2, n = 12), twice per week (training group 3, n = 12), or three times...
per week (training group 4, n = 7) or to a non training control group (n = 15). Training consisted of one set of 8 to 12 variable-resistance lumbar extensions to volitional muscular fatigue. Prior to and following 12 and 20 weeks of training, subjects were given a test that evaluated isolated isometric lumbar extension torque in a seated position at seven positions (angles) through a 72-degree range of motion. The control group showed no change in isometric torque. All training groups showed significant increases in lumbar extension torque at 12 and 20 weeks of training, whereas no significant differences were found among the groups with respect to the magnitude of torque gained. These findings show that isometric lumbar extension torque increases occur mainly within the first 12 weeks of training, although additional gains in the more extended positions can be affected when training is continued through 20 weeks. These data also indicate that training once every other week or once per week is as effective as training twice per week or three times per week for increasing isometric lumbar extension torque over 20 weeks.

Ettema G et al. (2008) conducted a study on effect of specific resistance training on over arm throwing performance. The main purpose of this study was to compare the effect of a specific resistance training program (throwing movement with a pulley device) with the effect of regular training (throwing with regular balls) on over arm throwing velocity under various conditions. The training forms were matched for total training load, ie, impulse generated on the ball or pulley device. Both training groups (resistance training n = 7 and regular training n = 6) consisted of women team handball players, and they were trained 3 times per week for 8 weeks, according to an assigned training program alongside their normal handball training. An increase in throwing velocity with normal balls after the training period was observed for both groups (P = .014), as well as
throwing with heavier balls and throwing like actions in the pulley device. Although the regular training group seemed to improve more (6.1%) in throwing velocity with normal balls than the resistance training group (1.4%), this difference was not statistically significant. These findings indicate that resistance training does not surpass standard throwing training in improvement of over arm throwing velocity.

John T. B. (1949) study includes results from a questionnaire sent to 33 physical educators who had the knowledge of the weightlifting program at the Oakland YMCA. They were asked two questions. "What factors influence men to participate in a weightlifting program?" and "Do you think training with weights is a worthy and beneficial activity? Factors most predominantly mentioned in answer to the first question were: seek physical development, dislike traditional competitive sports, which are concerned with health, lack of self-confidence or aggressiveness, lack social confidence, desire strength. The second preliminary investigation took the form of a personal interview with 50 weightlifters selected at random from the Oakland YMCA. They were asked the same two questions. Forty persons definitely stated that their primary interest was to "build up" their bodies. Then a personal inventory study was conducted on 100 YMCA male weightlifters and 100 other male YMCA athletes. Statistically significant differences between weightlifters and controls were found in all categories: present health, self-confidence, manly-individualistic. Training with weights probably appeals to a group that differs with respect to interest, attitudes, and personality from the rest of the active YMCA membership. A logical classification of the differentiating items indicates that the members of the weightlifting group feel more strongly than the controls that their health has improved, that basically they are shy, that they lack self-confidence, and that
they do not obtain satisfaction, through participating at a loss, in the more traditional physical activities. They want to be strong and dominant, emulating other strong men.

Trujillo, C. (1983) conducted a study on effects of weight training and running exercise intervention programs on the self-esteem of college women. Subjects were undergraduate females. (13 weight training, 12 running, and 10 controls). Change in self-esteem which was reported by any pre- to post-test differences for each individual participant was found to be significantly increased in both the weight training and running groups. The control group did not gain in self-esteem, but showed a slight decrease for this attribute. It is clear that although both the weight training and running groups reported a significant change in the level of self-esteem, the amount of actual change when compared between groups were significantly higher for the weight training group only. The point however, is that the group of women who exhibited the largest gain in self-esteem was the group which gained an average of 68% in body strength and expressed significant losses in certain bodily areas. Although 35% (4) of the running group felt both physically and psychologically better, 83% (11) of the weight training group felt the same way. High-intensity resistance training improves muscle strength, self-reported function, and disability in long-term stroke survivors.

2.2 STUDIES ON PLYOMETRIC TRAINING

Chimera N.J. et al. (2004) conducted a study on Effects of Plyometric Training on Muscle-Activation Strategies and Performance in Female Athletes. To evaluate the effects of plyometric training on muscle-activation strategies and performance of the lower extremity during jumping exercises. Subjects selected from twenty healthy national
collegiate athletic association division i female athletes. Experimental subjects performed plyometric exercises 2 times per week for 6 weeks. A significant (P < .037) increase in preparatory adductor-to-abductor muscle co-activation in the experimental group was identified, as well as a trend (P < .053) toward reactive quadriceps to hamstring muscle co-activation in the experimental group. Pearson correlation coefficients revealed that significant adaptations in muscle activity patterns. Although not significant of the experimental and control subjects had average increases of 5.8% and 2.0% in vertical jump height, respectively. The increased preparatory adductor activity and abductor-to-adductor co-activation represent preprogrammed motor strategies learned during the plyometric training.

Villarreal de et al. (2008) conducted a study on low and moderate plyometric training frequencies produces greater jumping and sprinting gains compared with high frequency. The purpose of this study was to examine 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 pre-training in any of the
variables tested. No significant changes were observed in the control group in any of the variables tested at any point. Short-term plyometric training using moderate training frequency and volume of jumps (2 days per week, 840 jumps) produces similar enhancements in jumping performance, but greater training efficiency (~ 12% and 0.014% per jump) comparing with high jumping (4 days per week, 1680 jumps) training frequency (~18% and 0.011% per jump). In addition similar enhancement 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.

**Miller Michael G et al. (2006)** conducted a study on the effects of a 6-week plyometric training Program on agility. The purpose of the study was to determine if six weeks of plyometric training can improve an athlete's 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.

Vossen J F et al. (2000) conducted a study on Comparison of Dynamic Push-Up Training and Plyometric Push-Up Training on Upper-Body Power and Strength. The purpose of this study was to compare dynamic pushup (DPU) and plyometric push-up (PPU) training programs on 2 criterion measures: (a) the distance achieved on a sitting, 2-handed medicine ball put, and (b) the maximum weight for 1 repetition of a sitting, 2-handed chest press. Thirty-five healthy women completed 18 training sessions over a 6-week period, with training time and repetitions matched for the DPU (n = 17) and PPU (n = 18) groups. Dynamic push-ups were completed from the knees, using a 2-second-up–2-second-down cadence. Plyometric push-ups were also completed from the knees, with the subjects allowing themselves to fall forward onto their hands and then propelling themselves upward and back to the starting position, with 1 push-up completed every 4 seconds. The PPU group experienced significantly greater improvements than the DPU group on the medicine ball put (p = 0.03). There was no significant difference between groups for the chest press, although the PPU group experienced greater increases.

Swanik K.A (2002) conducted a study on the effects of shoulder plyometric training on proprioception and selected muscle performance characteristics. The purpose
of this study was to determine the effect of plyometric training on proprioception, kinesthesia, and selected muscle performance characteristics in female swimmers. Twenty-four female division I swimmers were evaluated before and after a 6-week plyometric training program. Proprioception and kinesthesia were assessed for internal and external rotation at 0°, 75°, and 90% of the subject’s maximum external rotation. The Biodex II was used to assess strength characteristics at 60°/s, 240°/s, and 450°/s. Plyometric training sessions (2 times/week) involved 3 sets of 15 repetitions with a trampoline, weighted balls, and elastic tubing. A 2-way analysis of variance revealed significant improvement (P < .05) in proprioception at 0° moving into external rotation, as well as 75° and 90% moving into both internal and external rotation. Kinesthesia demonstrated significant improvement for all test conditions after plyometric training. Significant gains in selected muscle performance characteristics included time to peak torque (60°/s and 240°/s), amortization time (450°/s), and torque decrement (240°/s). This study suggests that plyometric activities may facilitate neural adaptations that enhance proprioception, kinesthesia, and muscle performance characteristics. Significant neuromuscular benefits may be attained if they are implemented earlier into shoulder rehabilitation programs.

Faigenbaum Avery D (2006) conducted a study on effects of medicine ball training on fitness performance of high-school physical education students. The purpose of this study was to examine the effects of medicine ball training on the fitness performance of high-school physical education students. Sixty-nine high-school students participated in a 6-week medicine training program during the first 10 to 15 minutes of each physical education class. A group of 49 students who participated in physical
education lessons but not medicine ball training showed as controls. Performance on the shuttle run, long jump, sit and reach flexibility, abdominal curl, medicine ball push-up, and medicine ball seated toss was assessed at baseline and post-training. Students who participated in the medicine ball training program made significantly greater gains on all fitness tests as compared to the control group. These data suggest that medicine ball training can enhance selected measures of speed, agility, power and muscular endurance when incorporated into a high school physical education class.

Abass A O (2009) conducted a study on comparative effect of three modes of plyometric training on leg muscle strength of university male students. This study determined the comparative effect of three modes of Plyometrics training [depth jumping, rebound jumping and horizontal jumping] on leg muscle strength of untrained University male students. Participants were forty untrained male University students within the age range of 18-27 years. The randomized pretest-posttest control group design was adopted. Subjects were randomly assigned to control group, and three experimental groups based on the types of plyometrics training adopted for the study. The training programme consisted of twelve weeks of interval training administered three times a week. Data collected were analyzed using the mean score, standard deviation and range. Analysis of Covariance [ANCOVA] was used to test for significant differences in the posttest measures among the treatment and control groups using the pretest score variation as covariates. Scheffe post hoc analysis was used to determine which of the means were significantly different. All hypotheses for the study were tested at 0.05 critical level. Findings revealed that only the depth jumping and rebound jumping training significantly altered leg muscle strength of subjects (P<0.05). Based on the findings, it was concluded
that plyometrics exercises with depth jumping and rebound jumping characteristics are best used in developing muscle strength of the lower extremities.

Luebbers PE et al. (2003) conducted a study on effects of plyometric training and recovery on vertical jump performance and anaerobic power. He examined the effects of 2 plyometric training programs, equalized for training volume, followed by a 4-week recovery period of no plyometric training on anaerobic power and vertical jump performance. Physically active, college-aged men were randomly assigned to either a 4-week (n = 19, weight = 73.4 +/- 7.5 kg) or a 7-week (n = 19, weight = 80.1 +/- 12.5 kg) program. Vertical jump height, vertical jump power, and anaerobic power via the Margaria staircase test were measured pretraining (PRE), immediately posttraining (POST), and 4 weeks posttraining (POST-4). Vertical jump height decreased in the 4-week group PRE (67.8 +/- 7.9 cm) to POST (65.4 +/- 7.8 cm). Vertical jump height increased from PRE to POST-4 in 4-week (67.8 +/- 7.9 to 69.7 +/- 7.6 cm) and 7-week (64.6 +/- 6.2 to 67.2 +/- 7.6 cm) training programs. Vertical jump power decreased in the 4-week group from PRE (8,660.0 +/- 546.5 W) to POST (8,541.6 +/- 557.4 W) with no change in the 7-week group. Vertical jump power increased PRE to POST-4 in 4-week (8,660.0 +/- 546.5 W to 8,793.6 +/- 541.4 W) and 7-week (8,702.8 +/- 527.4 W to 8,931.5 +/- 537.6 W) training programs. Anaerobic power improved in the 7-week group from PRE (1,121.9 +/- 174.7 W) to POST (1,192.2 +/- 189.1 W) but not the 4-week group. Anaerobic power significantly improved PRE to POST-4 in both groups. There were no significant differences between the 2 training groups. Four-week and 7-week plyometric programs are equally effective for improving vertical jump height, vertical jump power, and anaerobic power when followed by a 4-week recovery period. However,
a 4-week program may not be as effective as a 7-week program if the recovery period is not employed.

Murat Ateş et al. (2007) conducted a study on the effect of plyometric training on some physical and physiological parameters of 16-18 years old male soccer players. The study was carried out to determine the effect of plyometric training on some physical and physiological parameters of 16-18 years old male soccer players. A total of 24 soccer players (12 as experimental group and 12 as control group) volunteered to participate in the study. Both the groups regularly participated in soccer training and also the experimental group was trained by plyometric training method twice a week for 10 weeks. A pre-test and a post-test were applied to the groups before and after 10 weeks of training respectively. The physical and the physiological parameters of subject were tested by scientifically valid laboratory and field tests. In statistical analysis, paired sample t-test for within group analysis and independent sample t-test for between group analyses were used in SPSS 11.0 for Windows. After 10 weeks training period, it was found that there was significant difference between the pre-test and post-test of the following parameters of experimental group; IKAS, body fat percentage, anaerobic power, flexibility, 30 m speed run, aerobic power and 15 seconds repeated jump and body weight. On the other hand, in the control group, there was significant difference in all parameters, except anaerobic power and 15 seconds repeated jump. When the experimental group was compared with control group, no differences were found in the pre-test values of groups. However, in post-test, significant differences were observed in anaerobic power, flexibility and 15 seconds repeated jump values. In conclusion; it was found that 10 weeks plyometric training applied concurrent with the standard soccer
Training has positive effect on flexibility, anaerobic power, maximal power, 15 seconds repeated jump.

Diallo O et al. (2001) conducted a study on 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. The purpose of this study was to examine the effectiveness of plyometric training and maintenance training on physical performances in prepubescent soccer players. 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 for 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. The results demonstrate that short-term plyometric training programmes increase athletic performances in prepubescent boys. These improvements were maintained after a period of reduced training.

Reyment et al. (2007) conducted a study to examine the effects of plyometric training following a four week training program on vertical jump height, 40 yard dash, 10
yard dash, and anaerobic power. The subjects included 17, healthy, male Division 3 hockey players, between the ages of 18-24. All subjects were tested in the vertical jump, 40 yard dash time, 10 yard dash time, and anaerobic power using the Wingate Bike test prior to starting the plyometric program. The subjects then completed a four week plyometric training program and were retested. There were significant differences (p < .05) in the mean anaerobic power drop percentage p = .020, peak relative power p = .046, peak power p = .005, right foot vertical jump height (p = .046), left foot vertical jump height (p = .000). The findings suggested that two days of plyometric training a week for four weeks is sufficient enough to show improvements in single leg vertical jump height and overall power endurance. In contrast plyometric training two days a week for four weeks was not sufficient enough to show improvements in 40 yard dash times, 10 yd dash times, two foot vertical jump height, minimum power (W) values, and relative minimum power (W/kg) values.

Newton, R U (1994) conducted a study on Baseball throwing Velocity: a comparison of medicine ball training and weight training. This study examined the effect of upper body plyometric training, using medicine balls, and upper body conventional weight training on baseball throwing velocity and strength levels as assessed by a 6-RM bench press. Twenty-four junior development baseball players took part in an 8-week training study in conjunction with their baseball training. They were randomly allocated to one of three groups: a medicine ball training group, a weight training group, and a control group. The first group performed explosive upper body medicine ball throws, the weight training group performed conventional upper body weight training, and the control group only performed their normal baseball training. Pre- and post-training
measurements of throwing velocity and 6-RM bench press were recorded. The weight training group produced the greatest increase in throwing velocity and 6-RM strength. The medicine ball group showed no significant increase in throwing velocity but did show a significant increase in strength. For this group of non-strength-trained baseball players, it was more effective to implement a weight training program rather than medicine ball training to increase throwing velocity.

Ebbome et al. (2008) conducted the study on evaluation of plyometric intensity using electromyography. The purpose of this study was to investigate the motor unit activation of the quadriceps (Q), hamstring (H), and gastrocnemius (G) muscle groups during a variety of plyometric exercises to further understand the nature of these exercises. Twenty-three athletes volunteered to perform randomly ordered plyometric exercises, thought to cover a continuum of intensity levels, including two-foot ankle hops; 15-cm cone hops; tuck, pike, and box jumps; one- and two-leg vertical jump and reach; squat jumps with approximately 30% of their 1RM squat load; and 30- and 61-cm depth jumps. Integrated electromyographic data were analyzed for each exercise using one-way repeated-measures ANOVA. Results revealed significant main effects for the Q when all subjects are analyzed, as well as for separate analysis of men, women, subjects with vertical jumps greater than 50 cm, and those with vertical jumps less than or equal to 50 cm (p ≤ 0.05). Significant main effects were also found for the G muscle group in the analysis of all subjects, as well as for men and subjects with vertical jumps greater than 50 cm (p ≤ 0.05). No significant main effects were found for the H muscle group. Pairwise comparisons revealed a variety of differences among plyometric exercises. In some cases, plyometrics previously reported to be of high intensity, such as the depth jump,
yielded relatively little motor unit recruitment compared with exercises typically thought to be of low intensity. Results can assist the practitioner in creating plyometric programs based on the nature of the motor unit recruitment.

Sedano C. S. et al. (2009) conducted the study on effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. The aim of the present study was to examine how explosive strength, kicking speed, and body composition are affected by a 12-week plyometric training program in elite female soccer players. 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 were no significant time x group interaction effects for body composition. It could be 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.

Newton R.U. and McEvoy K. I (1994) conducted a study on the effect of upper body plyometric training, using medicine balls, and upper body conventional weight training on baseball throwing velocity and strength levels as assessed by a 6-RM bench press. Twenty-four junior development baseball players took part in an 8-week training study in conjunction with their baseball training. They were randomly allocated to one of three groups: a medicine ball training group, a weight training group, and a control group. The first group performed explosive upper body medicine ball throws, the weight training group performed conventional upper body weight training, and the control group only performed their normal baseball training. Pre- and post-training measurements of throwing velocity and 6-RM bench press were recorded. The weight training group produced the greatest increase in throwing velocity and 6-RM strength. The medicine ball group showed no significant increase in throwing velocity but did show a significant increase in strength. For this group of non-strength-trained baseball players, it was more effective to implement a weight training program rather than medicine ball training to increase throwing velocity.

2.3 STUDIES ON SKILL MOVEMENT TRAINING

Christie, C et al. (2007) stated that as limited research has focused on the physiological responses associated with cricket activity, the aim of this pilot study was to measure selected physiological responses during batting in a simulated high-scoring 1-day cricket game. Ten male university cricketers performed a batting specific work bout consisting of four sprints per over (six balls) for a seven over period. Testing was
conducted outdoors with players wearing full batting gear. All experimentation was conducted under temperate environmental conditions. During the simulated work bout, a portable on-line metabolic system (the k4b2) was attached to the subjects for the continuous assessment of selected physiological variables including heart rate (HR), ventilation (FB, VT and VE), oxygen uptake (\( VO_2 \)) and metabolic carbon dioxide (\( VCO_2 \)) production. Energy expenditure was calculated from the oxygen consumption responses and substrate use was calculated from the \( VO_2/VCO_2 \) responses. The results demonstrate that although the first over carried a statistically (\( p<0.05 \)) lower energetic cost than the remaining six overs, most physiological responses stabilized thereafter. This excluded the heart rate responses which increased significantly (\( p<0.05 \)) during the first three overs after which marginal increases were observed with no statistical difference between the last four overs (heart rate ranged from 149±19btmin-1 in the fourth over to 155±18btmin-1 in the last over). There was a mean energy expenditure of 2536 kJh-1 over the duration of the work bout.

Szymanski DJ et al. (2009) revealed about the contributing factors for increased bat swing velocity. Bat swing velocity is an important characteristic of successful hitters in baseball and softball. The purpose of this literature review is threefold. First, before describing what components and training methods have been investigated to improve bat swing velocity, it is necessary to discuss the importance of bat swing velocity and batted-ball velocity. The second purpose is to discuss bat weight during on-deck circle warm-up, bat weight during resistance training, resistance training with an overload of force, performance of additional supplemental resistance exercises, the relationship between strength, power, lean body mass, and angular velocity and bat swing velocity, and the
relationship between improvements in strength, power, lean body mass, and angular velocity and improvements in bat swing velocity. The third purpose of this review is to recommend some practical applications based on research results.

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

Petersen C J et al. (2004) conducted a study on effects of modified-implement training on fast bowling in cricket. The effects of training with overweight and underweight cricket balls on fast-bowling speed and accuracy were investigated in senior club cricket bowlers randomly assigned to either a traditional (n = 9) or modified-implement training (n = 7) group. Both groups performed bowling training three times a week for 10 weeks. The traditional training group bowled only regulation cricket balls (156 g), whereas the modified-implement training group bowled a combination of overweight (161-181 g), underweight (151-131 g) and regulation cricket balls. A radar gun measured the speed of 18 consecutive deliveries for each bowler before, during and after the training period. Video recordings of the deliveries were also analysed to determine bowling accuracy in terms of first-bounce distance from the stumps. Bowling speed, which was initially 108 +/- 5 km h (-1) (mean +/- standard deviation), increased in the modified-implement training group by 4.0 km x h(-1) and in the traditional training group by 1.3 km x h(-1) (difference, 2.7 km x h(-1); 90% confidence limits, 1.2 to 4.2 km x h (-1)). For a minimum worthwhile change of 5 km x h (-1), the chances that the true effect on bowling speed was practically beneficial/trivial/harmful were 1.0/99/< 0.1%. For bowling accuracy, the chances were 1/48/51%. This modified-implement training programme is not a useful training strategy for club cricketers.

Petersen C. J et al. (2009) conducted a study on movement patterns in cricket vary by both position and game format. We compared the movement patterns of
cricketers in different playing positions across three formats of cricket (Twenty20, One Day, multi-day matches). Cricket Australia Centre of Excellence cricketers (n = 42) from five positions (batting, fast bowling, spin bowling, wicket keeping, and fielding) had their movement patterns (walk, jog, run, stride, and sprint) quantified by global positioning system (GPS) technology over two seasons. Marked differences in movement patterns were evident between positions and game formats, with fast bowlers undertaking the greatest workload of any position in cricket. Fast bowlers sprinted twice as often, covered over three times the distance sprinting, with much smaller work-to-recovery ratios than other positions. Fast bowlers during multi-day matches covered 22.6 +/- 4.0 km (mean +/- s) total distance in a day (1.4 +/- 0.9 km in sprinting). In comparison, wicketkeepers rarely sprinted, despite still covering a daily total distance of 16.6 +/- 2.1 km. Overall, One Day and Twenty20 cricket required approximately 50 to 100% more sprinting per hour than multi-day matches. However, multi-day cricket's longer duration resulted in 16-130% more sprinting per day. In summary, the shorter formats (Twenty20 and One Day) are more intensive per unit of time, but multi-day cricket has a greater overall physical load.

Marshall R and René F (2003) conducted a study on the effect of a flexed elbow on bowling speed in cricket. This study examined whether such bowlers can produce an additional contribution to wrist/ball release speed by internal rotation of the upper arm. The kinematics of a bowling arm was calculated using a simple two-link model (upper arm and forearm). Using reported internal rotation speeds of the upper arm from baseball and water polo, and bowling arm kinematics from cricket, the change in wrist speed was calculated as a function of effective arm length, and wrist distance from the internal
rotation axis. A significant increase in wrist speed was noted. This suggests that bowlers who can maintain a fixed elbow flexion during delivery can produce distinctly greater wrist/ball speeds by using upper arm internal rotation.

Juanita W.J. et al. (2009) conducted a survey on towards the development of a conceptual model of expertise in cricket batting: A grounded theory approach. Data from semi-structured interviews with 14 male expert cricket batsmen, coaches, and administrators were used to generate a conceptual model of expertise in this sport. In the model, a favorable socio-developmental environment (support, vast investment in creative and challenging play, sibling rivalry) provides the essential foundation for the development of positive psychological attributes (mental toughness, self-belief and confidence, ability to cope with adversity, adoption of individualized routines/rituals), technical skill mastery (optimal balance, speed of downswing, versatility of shot execution) and superior visual-perceptual skill. Intrinsic motivators (fun, enjoyment, challenge and achievement, desire to be the best, “love of the game”, camaraderie) are regarded as essential to continuation and progression along developmental pathways. Facets of contemporary society and its constraints on free play emerged as one of the major limitations to the future development of expertise. The model has immediate implications for coaching practice, developmental policy, and future research approaches to identifying and nurturing sports talent.

Gabbett Tim et al. (2009) conducted a study on Game-Based Training for Improving Skill and Physical Fitness in Team Sport Athletes. The purpose of this paper is to provide a brief review of the relevant literature on game-based training, and summarise the advantages and disadvantages of this approach to training. At present, studies
investigating the effectiveness of game-based training are limited, with many of the suggested advantages and disadvantages of game-based training based on anecdotal evidence. Of the studies that have been performed, most have reported that game-based training offers a specific method of conditioning for team sport competition, but game-based training may not simulate the high-intensity, repeated-sprint demands of international competition. Game-based training has been reputed to offer a safe, effective method of conditioning for team-sport athletes that results in comparable and, in some cases, greater improvements in physical fitness and performance than traditional conditioning activities. While technical instruction training has been associated with a higher volume of skill executions (i.e., more 'touches'), game-based training has been associated with greater cognitive effort—an important condition for skill learning. Indeed, studies investigating skill learning have reported comparable and, in some cases, greater improvements in skill execution and decision-making following game-based training than training involving repetitious technical instruction. Collectively, these findings demonstrate the value of game-based training for improving skill and physical fitness in team sport athletes. Further studies investigating the long-term skill and physical benefits of game-based training are warranted.

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

Land MF and McLeod P. (2000) conducted a study about from eye movements to actions: how batsmen hit the ball. The purpose of the study was about, in cricket, a batsman watches a fast bowler's ball come toward him at a high and unpredictable speed, bouncing off ground of uncertain hardness. Although he views the trajectory for little more than half a second, he can accurately judge where and when the ball will reach him. Batsmen's eye movements monitor the moment when the ball is released, make a
predictive saccade to the place where they expect it to hit the ground, wait for it to bounce, and follow its trajectory for 100-200 ms after the bounce. We show how information provided by these fixations may allow precise prediction of the ball's timing and placement. Comparing players with different skill levels, we found that a short latency for the first saccade distinguished good from poor batsmen, and that a cricket player's eye movement strategy contributes to his skill in the game.

Stone K. J. et al. (2009) conducted a study on The Effect of 45 Minutes of Soccer-Specific Exercise on the Performance of Soccer Skills. The aim of the study was to examine the effect of fatigue, developed during prolonged high-intensity intermittent exercise, on the performance of soccer shooting and dribbling skill. Nine semiprofessional soccer players with a mean age of 20.7 ± 1.1 years volunteered to participate in the study. Participants completed a slalom dribble test and the Loughborough Soccer Shooting Test (LSST), before and directly following the performance of three 15-min bouts of a modified version of the Loughborough Intermittent Shuttle Test (LIST). Mean heart rates and mean 15-s sprint times remained unchanged across the three bouts of the LIST. Following the LIST slalom dribbling time increased significantly by 4.5 ± 4.0% (P = .009), while the mean total points scored during the LSST was significantly reduced by 7.6 ± 7.0 points (P = .012). When fatigued the frequency of shots in the LSST achieving the highest score of 5 points was reduced by 47% while the frequency of shots achieving the lowest 0 point score increased by 85%. Results show that while 45 min of exercise caused no decrements in sprint performance there were significant reductions in the ability to perform soccer-specific skills. Both the speed (dribbling time) and accuracy (shot performance) with which
soccer-specific skills were executed was impaired following exercise replicating one-half of a soccer match.

Petersen C. et al. (2009) conducted a study on variability in movement patterns during one day internationals by a cricket fast bowler. The time-motion characteristics and the within-athlete variability in movement patterns were quantified for the same male fast bowler playing One Day International (ODI) cricket matches (n = 12). A number of different time motion characteristics were monitored using a portable 5-Hz global positioning system (GPS) unit (Catapult, Melbourne, Australia). The bowler’s mean workload per ODI was 8 ± 2 overs (mean ± SD). He covered a total distance of 15.9 ± 2.5 km per game; 12 ± 3% or 1.9 ± 0.2 km was striding (0.8 ± 0.2 km) or sprinting (1.1 ± 0.2 km), whereas 10.9 ± 2.1 km was spent walking. One high-intensity (running, striding, or sprinting) repetition (HIR) occurred every 68 ± 12 s, and the average duration of a HIR effort was 2.2 ± 0.1 s. The player also completed 66 ± 11 sprints per game; mean sprint distance was 18 ± 3 m and maximum sprinting speed 8.3 ± 0.9 m s⁻¹. The movement patterns of this fast bowler were a combination of highly intermittent activities of variable intensity on the base of ~16 km per game. This information provides insight for conditioning coaches to determine the physical demands and to adapt the training and recovery processes of ODI fast bowlers.

Sheppard J.M. et al. (2008) conducted a study on Training Repeated Effort Ability in National Team Male Volleyball Players. This case study evaluated the effect of repeated lateral movement and jumping training on repeated effort ability in a group of national team male volleyball players. Twelve volleyball players were assessed on their volleyball-specific repeated movement and jumping abilities using a volleyball-specific
repeated effort test (RET) before and after 12 weeks of training. The athletes performed between 8 and 9 volleyball training sessions per week, with 5 to 6 of these sessions including specific training aimed at improving repeated effort ability. Typically these training sessions involved 8 to 12 repetitions of 2 to 3 block jumps over a 9-m lateral distance (i.e., the athletes had to perform jumps and lateral movements, typical of front court play in volleyball). Population-specific repeatability data were used to determine whether any changes that may have occurred in this study were beyond the minimal clinically important difference (MCID) for this testing procedure. Improvements in all variables of the RET were observed for each athlete involved in the study, with a small-to-moderate magnitude observed for the mean changes in each variable (Cohen’s $d$, 0.21 to 0.59). All of the improvements in the results exceeded the MCID. These findings demonstrate that the RET is sensitive to training-induced changes. Lateral movement speed and repeated lateral movement speed, as well as jumping and repeated jumping ability are trainable qualities in high-performance volleyball players.

2.4 STUDIES ON COMBINED TRAINING

Mathews, M, et al. (2009) conducted a study on the acute effects of heavy and light resistances on the flight time of a basketball push-pass during upper body complex training. The aim of this study was to investigate the acute effect of high-load and low-load complex training on upper-body performance-determined by the flight time of a basketball push-pass. Twelve competitive male athletes (21.8 ± 4.5 years, 82.0 ± 11.7 kg, 181.6 ± 5.6 cm), with at least 6 months weight training experience and no musculoskeletal disorders, undertook 3 testing conditions. Condition 1 involved 5 repetitions at 85% of a 1 repetition maximum (1RM) bench press; Condition 2 involved 5
repetitions of a 2.3-kg medicine ball push-pass; and Condition 3 was the control, where participants performed the equivalent time of the other conditions (~20 seconds). Each condition was preceded and followed by an electronically timed basketball push-pass. Results indicate a significant (3.99%, *P* = 0.001) reduction in flight time following the completion of Condition 1 (85% 1RM) but no significant changes (1.96%, *P* = 0.154) were seen following Condition 2 (medicine ball push-pass). Furthermore, there was a significant difference (*P* = 0.016) between Condition 1 (85% 1RM) and Condition 2 (medicine ball throw). This study appears to confirm previous research suggesting that high loads are required to elicit a potentiation effect. For those athletes wishing to produce a short-term enhancement of power, they should consider loads in the region of 85% 1RM. Results with the lower load showed greater variation, with some individuals responding and others not, because there appears to be an individual potentiation response to lighter loads.

Faigenbaum A D et al. (2007) conducted a study on effects of a short-term plyometric and resistance training program on fitness performance in boys aged 12 to 15 years. The purpose of this study was to compare 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.

Ebben William P. (2002) conducted a brief review on complex training. The effectiveness of plyometric training is well supported by research. 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.

Rahimi Rahman et al. (2006) conducted a study on Evaluation of plyometrics, weight training and their combination on angular velocity. The purpose of this study was to examine the effectiveness of six weeks of plyometric training, weight training and their combination on angular velocity during a 60-second test cycle ergometer. Based on their training, forty-eight male college students were divided into four 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 angular velocity was measured by a 15 and 60-second cycle ergometer test before and after a six-week training period. Subjects in each of the training groups were trained two days per week, whereas the control subjects did not participate in any training activity. The data was analyzed by a one-way analysis of variance (repeated measures design). The results showed that all the training treatments elicited significant (P<0.05) improvement in angular velocity. However, the combination training group showed signs of improvement in the angular velocity that was significantly greater than the improvement of the other two training groups (plyometric training and weight training). It was concluded that a combination of traditional weight training and plyometric drills "complex training" enhance angular velocity production in cycling. Therefore, complex training may help improve performance in sprint cycling that requires angular velocity, angular acceleration and power.

Fletcher I M and Matthew H (2004) conducted a study on Effect of an 8-week combined weight and plyometrics training program on golf drive performance. The purpose of this study was to determine the effect of a combined weights and plyometrics program on golf drive performance. Eleven male golfers' full golf swing was analyzed for club head speed (CS) and driving distance (DD) before and after an 8-week training program. The control group (n = 5) continued their normal training, while the experimental group (n = 6) performed 2 sessions per week of weight training and plyometrics. Controls showed no significant (p > or = 0.05) changes, while experimental subjects showed a significant increase (p < or = 0.05) in CS and DD. The changes in golf drive performance were attributed to an increase in muscular force and an improvement
in the sequential acceleration of body parts contributing to a greater final velocity being applied to the ball. It was concluded that specific combined weights and plyometrics training can help increase CS and DD in club golfers.

Kubachka, E. M (1966) conducted the study to find out the effects of plyometric, strength training, and body weight exercises on the power, strength, and endurance capacities of the trunk muscles were examined. Training sessions occurred twice per week for five weeks (a total of 10 training sessions). Plyometrics use two physiological properties of muscle, the stretch reflex and storage of elastic energy. When a rapid lengthening of a muscle occurs just prior to rapid shortening, a more powerful contraction results. Plyometrics significantly increased power (8.6%) and strength (45.9%). Strength training increased power (7.3%) and strength (82.5%). Body weight increased strength only (21.9%). Both plyometrics and strength training were as effective as each other. This study showed the rapid and substantial gains that can be made when plyometric or strength training is confined to a restricted set of muscles. No inference should be made that these improvements will be transferred to any other activity.

Ronnestad B R (2008) conducted a study on short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. The purpose of this study was to compare 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 \((PP_{20}, PP_{35}, \text{ and } PP_{50}, \text{ respectively})\), 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 \(PP_{20}\). 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 \(PP_{20}, PP_{35},\) 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.

2.5 STUDIES ON ROM VARIABLES

According to Behm et al. (1993) "Strength training increases strength most at the specific velocity of movement at which the training exercises are performed. Strength increases are progressively smaller at velocities farther removed from the training velocity. This velocity-specific training response has been observed in isokinetic training at different velocities, in a comparison of isometric exercise and ballistic weight lifting.
(movements performed as rapidly as possible), and in a comparison of conventional heavy resistance weight training and explosive jump training. Ss (M = 8; F = 8) trained 3 days per week for 16 weeks by doing attempted ballistic unilateral ankle dorsiflexions against resistance that either permitted the isometric contractions (one limb no movement) or a relatively high-velocity (5.23 rad/s on an isokinetic dynamometer) movement (other limb). Training sessions consisted of 5 x 10 contractions of each type. Both limbs showed similar increases in voluntary isometric rate of torque development (26%) and relaxation (47%) and in evoked tetanus rate of torque development (14%). Similar decreases in evoked twitch time to peak torque (6%) and half-relaxation time (11%) were also observed. These training adaptations, previously associated specifically with high-velocity resistance training, were produced by a training regimen that prevented an actual rapid movement occurring. Since this study positioned the body segment to be moved in a stretched position, that could be a requirement for a training effect to occur. For example, to throw a baseball faster, a practice activity would be to have the athlete lean back with the arm fully extended behind a position of maximum stretch. Then the movement is attempted but prevented.

Edelmann et al. (2005) conducted a study on the effects of plyometric training of the posterior shoulder and elbow. The purpose of this research was to examine the effectiveness of a 6-week plyometric training period on power production of the posterior shoulder and elbow musculature. Twenty-eight normal college-aged volunteers (5 men, 23 women) were divided into control and plyometric training groups. Both groups were pre- and post tested using shoulder and elbow isokinetic tests and the Closed Kinetic Chain Upper Extremity Stability Test. The plyometric training group (n = 13) showed
significant improvement in the power generated in the elbow extensor muscles; however, no other significant changes were observed within this group. The control group (n = 15) showed no significant changes in power output over the course of this study. It was concluded that plyometric training of the upper extremity enhances power production of the elbow extensor muscles. Therefore, plyometrics may help improve performance in overhead sports that require power.

Stueleken MC (2008) conducted a study on strength and range of motion in elite female cricket fast bowlers with and without a history of shoulder pain. This study aimed to determine the prevalence of shoulder pain in female cricket fast bowlers and compare the shoulder rotation range of motion and strength of those bowlers with and without a history of shoulder pain. The active range of motion and isokinetic strength of the shoulder internal and external rotators was assessed in the bowling and non-bowling shoulders of 26 elite Australian female fast bowlers. Twelve bowlers had a history of shoulder pain. There were significant bilateral differences in external rotation range of motion for those bowlers without a history of shoulder pain (p<0.05), and in internal rotation range of motion for both the total cohort and those bowlers with a history of shoulder pain (p<0.05). There were no bilateral differences in average torques or average torque ratios, nor were there any differences in rotation range of motion, torques or torque ratios in the bowling shoulder between bowlers with and without a history of shoulder pain. There was an association between concentric internal rotation torque for the bowling shoulder and years of fast bowling (r(s)=0.45). Given the relatively small number of elite female cricketers, future research in this field will need to recruit fast
bowlers from other cricket playing nations to increase the power of studies and provide more confidence in the statistical outcomes.

Flintl and Berger RA (1962) stated that the passive-range-of-motion (ROM) and callisthenic-type exercise programs are popular in rehabilitative settings and have been reported to alleviate the symptoms of LBP. Unfortunately, such programs do not provide progressive resistance for the lumbar musculature and thus are limited in their ability to increase lumbar strength. Few studies have attempted to increase the strength of the lumbar extensor muscles through progressive-resistance training. This study showed significant increases in trunk extension strength as a result of progressive-resistance training.

Zatsiorsky V et al. (1995) conducted a study on Free weights and weight resistance cable machines are a great mechanism for overloading the body as they provide resistance throughout an entire range of motion and require activation of the body’s stabilizer mechanisms to control movement. The speed of movement can vary from isometric to ballistic, while maximally recruiting large groups of muscle fibers. Free weights do have a shortcoming when it comes to performance enhancement for athletes. ‘One is limited in the amount of weight they can lift by the weakest point of the range of movement.’ After working through the ‘sticking point’ (weakest point), as the joint angle nears end range of motion, the muscles have greater leverage to perform the movement. So the greatest overload on the muscle is decreased as one works toward the end range of motion, which just so happens to be where most sporting movements occur (i.e.: the vertical jump, sprinting, pitching, etc).
Monteiro W D (2008) conducted the study on Influence of Strength Training on Adult Women's Flexibility. The purpose of the current study was to investigate the effect of 10 weeks of strength training on the flexibility of sedentary middle-aged women. Twenty women were randomly assigned to either a strength training group (n = 10; age, 37 ± 1.7 years; body mass, 65.2 ± 10.7 kg; height, 157.7 ± 10.8 cm; and body mass index, 25.72 ± 3.3 kg·m⁻²) or a control group (n = 10; age, 36.9 ± 1.2 years; body mass, 64.54 ± 10.18 kg; height, 158.1 ± 8.9 cm; and body mass index, 26.07 ± 2.8 kg·m⁻²). The strength training program was a total body session performed in a circuit fashion and consisted of 7 exercises performed for 3 circuits of 8 to 12 repetitions maximum (RM), except for the abdominal exercise which was performed for 15 to 20 RM. Flexibility measurements were taken for 10 articulation movements pre and post training: shoulder flexion and extension, shoulder horizontal adduction and abduction, elbow flexion, hip flexion and extension, knee flexion, and trunk flexion and extension. Pre and post training, 10 RM strength significantly increased (p < 0.05). Of the movements examined, only shoulder horizontal adduction, hip flexion and extension, and trunk flexion and extension demonstrated significant increases (p < 0.05). Neither elbow nor knee flexion showed a significant change with weight training. The control group showed no significant change in any of the flexibility measures determined. In conclusion, weight training can increase flexibility in previously sedentary middle-aged women in some, but not all joint movements.

Kolber MJ et al. (2009) examined the Shoulder joint and muscle characteristics in the recreational weight training population. Shoulder disorders attributed to weight training are well documented in the literature; however, a paucity of evidence-based
research exists to describe risk factors inherent to participation. Shoulder joint and muscle characteristics in the recreational weight training (RWT) population were investigated to determine specific risk-related adaptations that may occur from participation. Ninety participants, men between the ages of 19 and 47 (mean age 28.9), including 60 individuals who participated in upper-extremity RWT and 30 controls with no record of RWT participation, were recruited. Active range of motion (AROM), posterior shoulder tightness (PST), body weight-adjusted strength values, and agonist/antagonist strength ratios were compared between the RWT participants and the control group. Statistical analysis identified significant differences (p < 0.001) between the groups when analyzing shoulder mobility. The RWT participants had decreased mobility when compared with the control group for all AROM measurements except external rotation, which was greater. Strength ratios were significantly greater in the RWT group when compared with the control group (p ≤ 0.001), implying agonist/antagonist muscle imbalances. The findings of this investigation suggest that RWT participants are predisposed to strength and mobility imbalances as a result of training. The imbalances identified have been associated with shoulder disorders in the general and athletic population; thus, these imbalances may place RWT participants at risk for injury. Common training patterns are biased toward large muscle groups such as the pectorals and deltoids but neglect muscles responsible for stabilization such as the external rotators and lower trapezius. Exercise selection that mitigates strength and mobility imbalances may serve to prevent injury in this population. Clinicians and strength and conditioning professionals should consider the biomechanical stresses and adaptations associated with RWT when prescribing upper-extremity exercises.
Thrash K et al. (1987) conducted the study to determine the effects of weight training on the range of motion (flexibility) of ankle, trunk, and shoulder joints. There has been a common belief that strength could not be promoted without impairing flexibility. Thirteen male college students participated in an 11-week weight training program, exercising three times weekly, performing eight exercises involving all major muscle groups of the body. Using a flexometer, six flexibility tests, two of which were specific to each of the three joint areas, were administered pre- and post-training. Significant (p<=0.05) increases were observed in ankle dorsiflexion and shoulder extension. It was concluded that participation in a similarly structured weight training program to develop muscular strength would not impair flexibility but might increase it.

Karen Giles and Iris Musa (2008) conducted a survey on glenohumeral joint rotational range and non-specific shoulder pain in elite cricketers. The objective of this study was to determine if a glenohumeral joint internal rotation range of motion difference (IRD) and external rotation difference (ERD) exists between dominant and non-dominant shoulders of cricketers as demonstrated in other overhead sports, and, if present, to establish if differences exist between cricketers with and without a history of gradual onset non-specific shoulder pain. One hundred and nine elite male and female cricketers (11-35 years), representing 97% of the England and Wales national and West of England regional Under 13 teams participated. Cricketers who regularly bowl or throw overarm had significantly less internal and greater external dominant to non-dominant glenohumeral rotation. Wicket-keepers had tendencies for smaller differences that were still statistically significant. The results of this study support measurement of passive
glenohumeral joint rotation during musculoskeletal profiling and indicate a possible link between increased IRD and non-specific shoulder pain.

**Benjamin S. U. et al. (2000)** conducted a study on *The Benefit of a Single-Leg Strength Training Program for the Muscles around the Untrained Ankle: A Prospective, Randomized, Controlled Study*. Twenty subjects without any history of ankle injuries were randomly divided into a control and a training group. Both groups underwent isokinetic testing of the ankle muscles at the beginning and end of an 8-week period. The control group maintained normal activities between the tests. Half of the training group trained the dominant leg only and the other half trained the nondominant leg only for the 8-week period, three times per week. The subjects who trained the dominant leg improved peak torque values by 8.5% in the trained leg and 1.5% in the untrained leg. Similarly, the subjects who trained the nondominant leg improved peak torque values by 9.3% in the trained leg and 3.5% in the untrained leg. In contrast, the control group showed no significant change in peak torque, power, or endurance between the initial and final tests. With improvements in peak torque as high as 40% in the trained leg and a crossover benefit of 19% in the untrained leg in eccentric inversion, this strength training technique deserves further investigation in an injured population where the benefits may be more substantial.

**Gallo R. A et al. (2004)** conducted a study on *Flexion-Distraction Injury of the Thoracolumbar Spine during Squat Exercise with the Smith Machine*. Flexion-distraction injuries of the lumbar spine are often associated with lap belt-restrained passengers involved in motor vehicle collisions. Recently, we treated 2 weight lifters who sustained flexion-distraction injuries while performing squatting exercises with probable improper
technique and use of the Smith machine. The Smith machine is an apparatus that consists of a barbell linked to a vertical track by cylinder bearings and permits only vertical displacement of the barbell. The barbell must be rotated clockwise to disengage locking hooks before lifting can begin. Conversely, to secure the barbell, it must be turned counterclockwise and gently lowered onto a set of pegs, which are placed approximately 6 in apart from each other. Two adjustable brackets are mounted at the inferior extent of the lifter's range of motion for the exercise. These brackets catch the barbell if the lifter fails to engage the locking mechanism. Failure to use proper lifting techniques and improper use of the machine can lead to devastating consequences. We report on 2 weight lifters who sustained flexion-distraction injuries to the thoracolumbar spine while performing squats on a Smith machine. In both cases, the lifters were novices to the machine and weight lifting. They failed to engage the locking mechanism and lacked a spotter and proper placement of the safety brackets.

### 2.6 STUDIES ON PHYSICAL VARIABLES

Mathiowetz V. (1985) conducted a survey and has given us the Grip and pinch strength: normative data for adults. The primary purpose of this study was to establish clinical norms for adults aged 20 to 75+ years on four tests of hand strength. A dynamometer was used to measure grip strength and a pinch gauge to measure tip, key, and palmar pinch. A sample of 310 male and 328 female adults, ages 20 to 94, from the seven-county Milwaukee area were tested using standardized positioning and instructions. Right hand and left hand data were stratified into 12 age groups for both sexes. The highest grip strength scores occurred in the 25 to 30 age groups. For tip, key, and palmar pinch the average scores were relatively stable from 20 to 59 years, with a
gradual decline from 60 to 79 years. A high correlation was seen between grip strength and age, but a low to moderate correlation between pinch strength and age. The newer pinch gauge used in this study appears to read higher than that used in a previous normative study. Comparison of the average hand strength of right-handed and left-handed subjects showed only minimal difference.

Koley S. et al. (2009) conducted a study on an association of hand grip strength with some anthropometric variables in Indian cricket players. The purpose of this study was of two-fold, firstly, to compare the hand grip strength (both right and left) and twelve anthropometric variables of cricketers with their control counterparts and, secondly, to search the correlation of hand grip strength with those anthropometric variables in cricketers. To solve this purpose, a total of 103 district and state level male cricketers from Amritsar, Punjab, India, aged 17 – 21 years (mean 18.29 ± 2.21) were selected purposively as the samples of the study along with an adequate control group (n = 101). The findings of the present study indicate that cricketers have higher mean values in six variables and lesser mean values in seven variables than their control counterparts, showing statistically significant differences (P ≤ 0.05) in all the variables (except arm muscle area) between them. In cricketers, right and left hand grip strength have significantly positive correlations with all the variables studied except percent lean body mass. From the findings of the present study, it may be concluded that, hand grip strength might be an acceptable indicator for the excellent performance in cricket as well as a useful selection criterion for this sport.

Delextrat A, and Cohen D (2009) conducted a study on strength, power, speed, and agility of women basketball players according to playing position. The aim of the
present study was to investigate the effect of playing position on strength, power, speed, and agility performances of women basketball players. Thirty subjects playing at national level participated in this study. They were divided into 3 groups according to playing position: guards (positions 1 and 2), forwards (positions 3 and 4), and centers (position 5). Each subject performed 8 tests presented in a random order: The 30-second Wingate Anaerobic test (WAnT), isokinetic testing of the knee extensors, 2 types of jump tests, a 20-m sprint, the agility T-test, a suicide run, and a basketball chest pass. Statistical differences between playing positions were assessed using a 1-way analysis of variance (ANOVA) and Scheffe post hoc analyses. Results showed that guards performed significantly better than centers for the relative peak and mean power achieved during the WAnT (+13% and +16.9%, respectively), relative peak torque of knee extensors (+19.5%), single-leg jump (+21.8), suicide run (+7.5%), and agility T-test (+6.4%, p < 0.05). In addition, guards achieved significantly better performances than forwards in the suicide run test (+7.1%) and forwards were characterized by a greater peak torque of the knee extensors compared to centers (+22.1%). These results indicate that specific fitness training must be undertaken according to playing position. The ability to perform the suicide run, the single-leg jump, and the different movements involved in the agility T-test must be developed in guards. In contrast, speed over short distances and strength development of lower body and upper body should be performed by all playing positions.

Hughes SS et al. (2004) conducted a study on effect of grip strength and grip strengthening exercises on instantaneous bat velocity of collegiate baseball players, Bat velocity is considered to be an important factor for successful hitting. The relationship between grip strength and bat velocity has not been conclusively established. The
purposes of this study were to determine the relationship of grip strength to bat velocity and to ascertain whether the performance of resistance training exercises designed to specifically target the forearms and grip would significantly alter bat velocity. The subjects for this study were 23 male members of a varsity baseball team at a National Collegiate Athletic Association Division II school. The Jamar hand dynamometer was used to test grip strength, and the SETPRO Rookie was used to measure instantaneous bat velocity at the point of contact with the ball. Subjects were randomly divided into an experimental group and a control group. For 6 weeks, both groups participated in their usual baseball practice sessions, but the experimental group also performed extra forearm and grip strengthening exercises, whereas the control group did not. Pretest and posttest correlations between grip strength and bat velocity revealed no significant relationship between grip strength and bat velocity (pretest $r = 0.054$, $p = 0.803$; posttest $r = 0.315$, $p = 0.145$). A dependent t-test performed on all subjects revealed that a significant ($p = 0.001$) increase in bat velocity did occur over the course of the study. A covariate analysis, employing pretest bat velocity as the covariate, revealed no significant difference ($p = 0.795$) in posttest bat velocity scores between the experimental and control groups. Thus, increases in bat velocity occurred, but the differences were similar for both the experimental and control groups. The findings of this study suggest that grip strength and bat velocity are not significantly related, and that the allocation of time and energy for added training of the forearms in order to improve grip strength for the purpose of increasing bat velocity may not be warranted.
2.7 STUDIES ON PHYSIOLOGICAL VARIABLES

Dixon CB, and Andreacci JL. (2009) conducted a study on effect of resistance exercise on percent body fat using leg-to-leg and segmental bioelectrical impedance analysis in adults. The purpose of this study was to examine 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. 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 body composition assessment.

Noakes T.D. and Durandt J.J (2000) reveals about the physiological requirements of cricket, despite its long history and global appeal, relatively little is known about the physiological and other requirements of cricket. It has been suggested that the physiological demands of cricket are relatively mild, except in fast bowlers during prolonged bowling spells in warm conditions. However, the physiological
demands of cricket may be underestimated because of the intermittent nature of the activity and the generally inadequate understanding of the physiological demands of intermittent activity. Alternatively, it could be hypothesized that superior power and endurance fitness may be required to cope with the repeated eccentric muscle contractions required in turning and in bowling and which may account for fatigue and risk of injury in cricket. If this is the case, the fitness of cricketers may be increased and their risk of injury reduced by more specific eccentric exercise training programmes.

Sotiropoulos A. et al. (2009) conducted a study on the effect of a 4-week training regimen on body fat and aerobic capacity of professional soccer players during the transition period. The purpose of this study was to evaluate 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 x kg (-1) x min (-1)) was a 2 x 2 (Groups x Measures), with Groups as a between-subjects factor and Measures as a within-subjects factor. The level of significance was set at p < or = 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). The findings of the study 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.

Kraemer W. J. et al. (2000) conducted a study about the influence of Resistance Training Volume and Periodization on Physiological and Performance Adaptations in Collegiate Women Tennis Players. The purpose of this investigation was to examine the effect of volume of resistance exercise on the development of physical performance abilities in competitive, collegiate women tennis players. Twenty-four tennis players were matched for tennis ability and randomly placed into one of three groups: a no resistance exercise control group, a periodized multiple-set resistance training group, or a single-set circuit resistance training group. No significant changes in body mass were observed in any of the groups throughout the entire training period. However, significant increases in fat-free mass and decreases in percent body fat were observed in the periodized training group after 4, 6, and 9 months of training. A significant increase in power output was observed after 9 months of training in the periodized training group only. One-repetition maximum strength for the bench press, free-weight shoulder press, and leg press increased significantly after 4, 6, and 9 months of training in the periodized training group, whereas the single-set circuit group increased only after 4 months of training. Significant increases in serve velocity were observed after 4 and 9 months of training in the periodized training group, whereas no significant changes were observed in the single-set circuit group. These data demonstrate that sport-specific resistance training using a periodized multiple-set training method is superior to low-volume single-
set resistance exercise protocols in the development of physical abilities in competitive, collegiate women tennis players.

**Teng W M et al. (2008)** conducted a study on effects of a Resistance Training Programme on Isokinetic Peak Torque and Anaerobic Power of 13-16 Years Old Taekwondo Athletes. The purpose of this study was to determine the effect of a 12 week (2 days per week) resistance training programme at an intensity of 50% of 1RM in adolescent males (13-16 years old) male taekwondo athletes on their isokinetic peak torque and anaerobic power. The intervention group (n=12) aged 14±1 years, participated in the prescribed resistance training programme along with the existing taekwondo skill/drill training (2 days/week), while the control group (n=11) aged 14±1 years, participated in an existing taekwondo skill/drill training only. Anaerobic power was estimated from Wingate anaerobic test. Anisokinetic dynamometer (Biodex multi-joint system 3 pro, New York) was used in the collection of data from the knee (flexion/extension) and hip (flexion, extension, abduction and adduction) joints. Mean anaerobic power and peak anaerobic power in the intervention group increased 9% and 10%, respectively. However, these two variables in the control group significantly decreased from mid training to post training (11.5% and 16% respectively), (p<0.001). There were no significant increase in peak torque, relative peak torque, average torque and average power on knee extension/flexion and hip extension/flexion in the intervention group. However, isokinetic hip average adduction power significantly (32%) increased from pre to mid training (p<0.01) in the intervention group. In the control group, there were significant decreased on isokinetic hip average flexion power (22%) and isokinetic hip average abduction power (34%) from pre to post training and mid to
post training respectively (p<0.01). Hence it is concluded that the prescribed resistance training was able to elicit a significant increase in some of the isokinetic strength variables. However, it did not administer any effect on anaerobic power of the taekwondo athletes.

2.8 STUDIES ON PSYCHOLOGICAL VARIABLES

John Wayne C J (2005) conducted a study on Analysis of the Components of Mental Toughness in Sport. The purpose of this study was to identify the components of mental toughness as perceived by National Collegiate Athletic Association (NCAA) coaches and was guided by two fundamental questions: what are the essential components of mental toughness? And to what degree are these components teachable (trainable). The results also indicated the degree of teachability (trainability) of each component. A unique relationship between teachability and trainability was also revealed in this study. These findings provide a better understanding of the components of mental toughness and support the need for its development in sport.

Kuan G and Jolly R (2007) conducted a study on Goal profiles, mental toughness and its influence on performance outcomes among Wushu athletes. This study examined the association between goal orientations and mental toughness and its influence on performance outcomes in competition. Wushu athletes (n = 40) competing in Intervarsity championships in Malaysia completed Task and Ego Orientations in Sport Questionnaire (TEOSQ) and Psychological Performance Inventory (PPI). Using cluster analysis techniques including hierarchical methods and the non-hierarchical method (k-means cluster) to examine goal profiles, a three cluster solution emerged viz. cluster 1 - high task and moderate ego (HT/ME), cluster 2 - moderate task and low ego (MT/LE)
and, cluster 3 - moderate task and moderate ego (MT/ME). Analysis of the fundamental areas of mental toughness based on goal profiles revealed that athletes in cluster 1 scored significantly higher on negative energy control than athletes in cluster 2. Further, athletes in cluster 1 also scored significantly higher on positive energy control than athletes in cluster 3. Chi-square ($\chi^2$) test revealed no significant differences among athletes with different goal profiles on performance outcomes in the competition. However, significant differences were observed between athletes (medallist and non-medallist) in self-confidence ($p = 0.001$) and negative energy control ($p = 0.042$). Medallist's scored significantly higher on self-confidence ($mean = 21.82 \pm 2.72$) and negative energy control ($mean = 19.59 \pm 2.32$) than the non-medallists (self confidence-$mean = 18.76 \pm 2.49$; negative energy control mean $= 18.14 \pm 1.91$).

Montare A. (2009) stated that the use of the simplest chronoscope (a falling meterstick) to measure visual reaction time (RT) in college students of both sexes is described. Tests of three hypotheses showed that (1) mean simple RT was significantly faster than long-standing population approximations and (2) a single-factor, repeated-measures, sequential-treatment analysis of variance design replicated Donders' long-standing findings that simple RT was significantly faster than choice RT; simple RT was significantly faster than discriminative RT; and that discriminative RT was significantly faster than choice RT. Also, (3) eta-squared effect size ($\eta^2$) computed on significant interindividual subject differences accounted for more variability than the $\eta^2$ effect size computed on significant differences between treatments. It was concluded that (1) the simplest chronoscope's methodology may have contributed to the significantly faster mean simple RT; (2) interindividual differences in RT should no longer be routinely
ignored or eliminated; and (3) a repeated-measures analysis of variance design which tests for both group and interindividual differences can yield reaction time results of interest to both experimental and differential psychology.

**Jacobson JM (1986)** conducted a study to determine if direction of response affects reaction time, we measured the time for hand response to a visual stimulus, using a sensitive, microprocessor-based testing device to determine simple reaction time (RT), choice RT, and decision time. Mean simple RT was $207 \pm 3.7$ msec. (mean $\pm$ SEM); mean choice RT was $268 \pm 4.2$ msec; and mean decision time was $61$ msec. No differences were noted for leftward versus rightward movements, or midline versus lateral movements. Choice RT increased by $1.49$ msec./yr. of age. Simple RT increased significantly with age for the non dominant hand, but not for the dominant hand. Right-handed subjects were more rapid with the dominant hand for choice RT. We conclude that dominance of hand tested and test initiation mechanism has major effects, but direction of movement in the lateral plane has little effect on reaction time.

**Daniel F. G et al. (2009)** conducted a study on Evaluation of a Mental Toughness Training Program for Youth-Aged Australian Footballers: I. A Quantitative Analysis. The purpose of this study was to evaluate the effectiveness of two different psychological skills training (PST) packages in enhancing mental toughness among three youth-aged (under 15 years old) Australian football teams. We compared a program targeting the keys to mental toughness identified with a more traditional PST program targeting self-regulation, arousal regulation, mental rehearsal, attentional control, self-efficacy, and ideal performance state as well as a control group. Overall, both intervention groups reported more positive changes in subjective ratings of mental toughness, resilience, and
flow than the control group. Similar ratings for mental toughness were reported by the parents and coaches. Both PST packages appeared to be equally effective in enhancing mental toughness.

Connaughton D et al. (2008) conducted a study on the development and maintenance of mental toughness: Perceptions of elite performers. Seven participants from a previous study agreed to be interviewed about the development of mental toughness. We also aimed to determine whether mental toughness requires maintenance. Semi-structured interviews were conducted to elicit the participants' perceptions of how mental toughness is cultivated and retained. Findings indicated that the development of mental toughness is a long-term process that encompasses a multitude of underlying mechanisms that operate in a combined, rather than independent, fashion. In general, these perceived underlying mechanisms related to many features associated with a motivational climate (e.g. enjoyment, mastery), various individuals (i.e. coaches, peers, parents, grandparents, siblings, senior athletes, sport psychologists, team-mates), experiences in and outside sport, psychological skills and strategies, and an insatiable desire and internalized motives to succeed. It was also reported that once mental toughness had been developed, three perceived underlying mechanisms were required to maintain this construct: a desire and motivation to succeed that was insatiable and internalized, a support network that included sporting and non-sporting personnel, and effective use of basic and advanced psychological skills. Practical implications and future avenues of research are discussed.

Stephen J. B et al. (2005) conducted a research on mental toughness is a critical element in contemporary international cricket. However, little is known beyond the
obvious basics of what constitutes mental toughness in an English cricketer. This study addressed two main objectives: 1) develop a greater understanding of what mental toughness is within cricket, and 2) identify how existing mentally tough English cricketers developed their mental toughness. Twelve English cricketers identified as being among the mentally toughest during the previous 20 years were interviewed. Analysis of the focused interview transcripts identified the critical role of the player's environment in influencing 'Tough Character,' 'Tough Attitudes,' and 'Tough Thinking.' The global themes are presented in a mental toughness framework that has been used to disseminate the findings to the cricket coaching and playing population in England. The contrasting and complementary nature of the global themes are used to help provide a structural appreciation of the need for consistent interaction between environment, character, attitudes, and thinking in order that a performer can consistently be considered as mentally tough in cricket. Implications of the findings in relation to the delivery of sport psychology support within English cricket are also highlighted.

Crust L and Azadi K (2010) conducted the study on mental toughness and athletes' use of psychological strategies. In this study, we assessed the relationship between mental toughness and athletes' use of psychological performance strategies. Sixty-seven male (mean age 22.6 years, s=5.0) and 40 female (mean age 21.1 years, s=2.8) athletes, who competed at club/university to national standard in a variety of sports, participated in the study. Participants completed the MTPQ4S (Clough et al., 2002) to measure mental toughness, and the Test of Performance Strategies (TOPS; Thomas et al., 1999) to measure the use of psychological strategies in practice and competition. Results of Pearson correlations and linear regression analyses revealed that self-talk,
emotional control, and relaxation strategies were significantly and positively ($r=0.26$ to $0.37$, $P<0.01$) related to mental toughness in both practice and competition. Of the MTQ48 subscales, commitment was found to load most frequently against performance strategies and thus it is possible that the results of this study reflect highly committed performers seeking performance enhancement strategies. Consistent with theoretical predictions, athletes of county standard and above reported significantly higher mental toughness than club/university athletes ($t_{105}=-2.25$, $P=0.03$).

**Jones et al. (2007)** conducted a study on a Framework of Mental Toughness in the World's Best Performers. The authors conducted an investigation of mental toughness in a sample population of athletes who have achieved ultimate sporting success. Eight Olympic or world champions, 3 coaches, and 4 sport psychologists agreed to participate. Qualitative methods addressed 3 fundamental issues: the definition of mental toughness, the identification of its essential attributes, and the development of a framework of mental toughness. Results verified the authors' earlier definition of mental toughness and identified 30 attributes that were essential to being mentally tough. These attributes clustered under 4 separate dimensions (attitude/mindset, training, competition, post competition) within an overall framework of mental toughness. Practical implications and future avenues of research involving the development of mental toughness and measurement issues are discussed.

**Males J. R. et al. (2006)** conducted a study on Team Process and Players' Psychological Responses to Failure in a National Volleyball Team. The present study investigated the psychological experiences of elite athletes in a team that failed using qualitative methods informed by reversal theory. Five athletes, from a national men's
volleyball team, playing in a European tournament completed a post-game review after each of 6 games. After the tournament, each player took part in in-depth semi-structured interviews, prompted by their post-game reviews. The results indicated that unrealistic expectations, poor team motivation, a negative coaching style, and faulty team process around game performance played an important role in the failure of this team. Also, inappropriate met motivational states and state reversals were found to have had a negative impact on team performance. Several consultant recommendations for enhancing team motivation and functioning are identified.

Tucker, L. A. (1982) conducted a study on Weight Training Experience and Psychological Well-Being. For that purpose 113 University males were administered a test to assess self-concept, body satisfaction, extraversion, and neuroticism. They also reported the number of months they had trained with weights. Apparently, the more weight training reported by the subjects, the more self confident and satisfies they tended to be. Similarly, the males who indicated that they had trained relatively often with weights in the past showed the most positive attitudes toward their body parts and processes. They also tended to be significantly more sociable, impulsive, and outgoing that were the males who reported relatively few months of experience training with weights. Although the more experienced weight trainers displayed the more favorable psychological profiles, they "lied" or reported in a socially desirable fashion significantly less than the less experienced subjects. From the results, increased credence must be afforded the assertion that weight training can play a significant part in the mental health and well-being of males. This study suggests that as weight-training experience increases,
global self concept, body cathexis, and extraversion tend to increase commensurately and lie-scale scores tend to decrease proportionately in males.

**Jean B RV et al. (1989)** conducted a study on effects of Weight Training Frequency on the Self-concept of College Females. For that purpose 51 subjects weight trained 3 days per week for 12 weeks, 53 subjects weight trained 2 days per week for 12 weeks, and 52 subjects served as controls. Based upon the findings of this study, self-concept of college females seems to increase as a result of strength training two days per week or three days per week.

**William T J (1991)** conducted a study on effects of Different Weight Training Routines on Mood States. Mood states of nine males and nine females were examined before and after 6 different weight lifting workouts. "Stronger perception of negative moods including tension, depression and fatigue resulted from higher work, lower weight with higher repetitions per set and shorter inter-set rest periods. An individual engaged in a strength type workout is reinforced by seeing improvements in strength, feeling unpressured, having time to talk to friends in the weight room, seeing a relatively high amount of weight moved and being under less cardiopulmonary, metabolic, and thermal stress. Individuals whose goals are bodybuilding, the training of local muscle endurance or completion of a full workout in a short amount of time are subject to the psychological and physiological stresses mentioned previously. In order to maintain a positive attitude under such conditions and adhere to a demanding routine, the trainee would have to be more goal-oriented or be provided with a creative workout design that incorporates a variety of effective reinforcements."
Patty F. S. (1983) conducted a study on Physique, Body Composition, and Psychological Characteristics of Competitive Female Body Builders. Body composition and Psychological characteristics of ten competitive female body builders were examined. Psychological testing included a battery of 5 psychological inventories. Psychologically, competitive female body builders were found to be somewhat less anxious, neurotic, depressed, angry, and confused and more extraverted, vigorous, and self-motivated than the general population. This psychological profile reflects positive mental health and is remarkably congruent with the psychological profile of elite male athletes. These data are consistent with the viewpoint that positive mental health is associated with competitive athletic success.

2.9 STUDIES ON PERFORMANCE VARIABLES

Szymanski DJ et al. (2004) conducted a study on effect of 12 weeks of wrist and forearm training on high school baseball players. This study examined the effect of 12 weeks of wrist and forearm training on male high school baseball players (mean age = 15.3 +/- 1.1 years). Participants (N = 43) were tested for 10 repetition maximum (RM) wrist barbell flexion, wrist barbell extension, dominant (D) and nondominant (ND) hand-forearm supination, D and ND forearm pronation, D and ND wrist radial deviation, D and ND wrist ulnar deviation, D and ND grip strength, and a 3RM parallel squat (PS) and bench press (BP). Group 1 (n = 23) and group 2 (n = 20), randomly assigned by a stratified sampling technique, performed the same resistance exercises while training 3 days a week for 12 weeks according to a stepwise periodized model. Group 2 also performed wrist and forearm exercises 3 days a week for 12 weeks to determine if additional wrist and forearm training provided further wrist and forearm strength.
improvements. All wrist and forearm strength variables were measured before and after 12 weeks of training. The 3RM PS and BP were measured at 0 and after 4, 8, and 12 weeks of training. Both groups significantly increased wrist and forearm strength (kg +/- SD) except 10RM D and ND forearm supination for group 1 (p < 0.05). Group 2 showed statistically greater improvements (p < 0.05) in all wrist and forearm strength variables than did group 1 except for D and ND grip strength. Predicted 1RM (kg +/- SD) PS and BP increased significantly (p < 0.05) after weeks 4, 8, and 12 for both groups. These data indicate that a 12-week stepwise periodized training program can significantly increase wrist, forearm, PS, and BP strength for both groups. Additionally, group 2 had further wrist and forearm strength gains.

Gabbett and Tim J (2008) conducted a study on Do Skill-Based Conditioning Games Offer a Specific Training Stimulus for Junior Elite Volleyball Players. This study investigated the specificity of skill-based conditioning games and compared the effectiveness of skill-based conditioning games and instructional training for improving physical fitness and skill in junior elite volleyball players. Twenty-five junior volleyball players (mean age ± SE, 15.6 ± 0.1 years) participated in this study. Heart rate data were collected on all players during the Australian Junior Volleyball Championships. After the competition, players were randomly allocated into a skill-based conditioning games group (n = 12) or an instructional training group (n = 13). Each player participated in a 12-week training program that included 3 organized court training sessions per week. No significant differences (P > 0.05) were detected between competition and skill-based conditioning games for the percentage of time spent in low-intensity, moderate-intensity, and high-intensity activities. Skill-based conditioning games induced improvements in
vertical jump, spike jump, speed, agility, upper-body muscular power, and estimated maximal aerobic power, whereas technical instruction improved only spike jump and speed. Conversely, instructional training induced meaningful improvements in all measurements of skill, whereas improvements in technical skill after skill-based conditioning games were uncommon and typically small. The results of this study show that skill-based conditioning games offer a specific training stimulus to simulate the physiological demands of competition in junior elite volleyball players. Although the improvements in physical fitness after training were greater with skill-based conditioning games, instructional training resulted in greater improvements in technical skill in these athletes. These findings suggest that a combination of instructional training and skill-based conditioning games is likely to confer the greatest improvements in fitness and skill in junior elite volleyball players.

Danhoff, G.W. et al. (1993) conducted a study on Psychological and Physical Changes Resulting From a 14-Week, Off-Season Conditioning Program in Volleyball Players. The present study is unique as it demonstrates that as members of a team, supposedly in good shape having just finished the season, when put on a strength training regimen, showed dramatic improvements in strength, power, and psychological well-being. Furthermore, the data indicate that a reasonable goal of off-season conditioning programs should be to enhance both psychological well-being and physical skills.

2.10 SUMMARY OF REVIEW OF LITERATURE

The relevant literature collected after exhaustive review of the different sources throw an ample light with regard to sports specific training methods of strength training,
plyometric training, skill movement training and their combinations on range of motion, physical, physiological, psychological and performance related variables. Thus this chapter describes the review of the related literature; which is essential to interpret the results to support the present problem. This also has its relevancy with the various cricket performances that are required to train at different modalities of intensities and frequencies of sports specific training with skill movement training.

More than twenty five studies are very closely related to the present study are given as a supportive evidence in the fourth chapter under the heading of discussion on findings.