CHAPTER - II

LITERATURE SURVEY
CHAPTER 2

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Literature survey has served as a guideline to identify the different training programmes designed for peak performance in sports and games. This chapter is divided into five pertinent headings: comparison of non-periodization vs. periodization, influence of resistance training volume and periodization, effects of resistance training on women’s strength/power and occupational performances, resistance-training regimens with varied combinations of low, moderate and high intensity exercises, influence of exercise training on physical, physiological and performance adaptations which forms the background for the present study.

2.1 STUDIES ON COMPARISON OF NON-PERIODIZATION VS. PERIODIZATION

The majority of earlier research has compared non-periodized programmes to periodized training has shown periodized training elicited superior results in one or more performance measures relating to strength, power and high intensity exercise endurance (Kraemer et al. 1997)

Willoughby (1993) compared a periodized trained group and a non-periodized trained group that the periodized programme elicited a greater upper body and lower body strength gain for previously weight-trained males. The non-periodized trained with an intensity that was kept constant throughout the 16 week training programme. The periodized group’s training programme consisted of four weeks of 5 sets of 10 repetitions (5x10) at 79% of 1 RM, four weeks of 6x8 at 83% of 1 RM, four weeks of 3x6 at 88% of 1 RM and four weeks of 3x4 at 92% of 1 RM. At training
weeks of 8, 12 and 16; the periodized training group demonstrated significantly greater improvements in strength levels in the bench press compared to the non-periodized group. For the squat, the periodized group demonstrated a significantly greater strength increases/levels compared to the non-periodized groups at week 16.

In the Kraemer’s study (Kraemer et al., 2000), 24 women collegiate tennis players were matched by playing ability and randomly placed into three groups: 1) no resistance control group, 2) single-set circuit resistance training group and 3) periodized multi-set circuit resistance training group. After four, six and nine months of training the periodized training group significantly increased one-repetition maximum strength for bench press, free-weight shoulder-press and leg press. The single-set circuit group only increased strength after the initial 4 months of training. Only the periodized group significantly increased power output ability following nine months of training. Significant increase in serve velocity was observed after four and nine months of training in the periodized group and not in the single-set group. This study shows that sport specific resistance training using periodized training protocol is superior to low-volume single set resistance training in the development of physical abilities.

It is believed that more frequent changes in stimuli, such as those presented by the periodized training programme, facilitated the greater strength development. However, a clear criticism of the Kraemer study was that training volume differed greatly between the two training groups. Thus it cannot be determined if the training volume, periodization, or a combination of these two variables produced the significantly greater training adaptations in the multi-set, LP group.
The underlying physiological mechanisms that explain the differences between periodized and non-periodized programmes remain to be fully investigated and explained (Fleck and Kraemer 1997). Some researchers believe that neural adaptations and the avoidance of overtraining are possible factors for periodized trainings superiority (Stone et.al., 1999)

Faigenbaum et al. (1999) conducted a study to compare the effects of a low repetition-heavy load resistance training programme and a high repetition-moderate load resistance training programme on the development of muscular strength and muscular endurance in children. It was recorded that one RM leg extension strength significantly increased in both exercise groups compared with that in the control subjects. Increases of 31.0% and 40.9%, respectively, for the low repetition-heavy load and high repetition-moderate load groups were observed. Leg extension muscular endurance significantly increased in both exercise groups compared with that in the control subjects, although gains resulting from high repetition-moderate load training (13.1 ± 6.2 repetitions) were significantly greater than those resulting from low repetition-heavy load training (8.7 ± 2.9 repetitions). On the chest press exercise, only the high repetition-moderate load exercise group made gains in 1-RM strength (16.3%) and muscular endurance (5.2 ± 3.6 repetitions) that were significantly greater than gains in the control subjects. Thus the study concluded that these findings support the concept that muscular strength and muscular endurance can be improved during the childhood years and favor the prescription of higher repetition-moderate load resistance training programmes during the initial adaptation period.
Rhea (2002) compared linear periodization (LP) and daily undulating periodization (DUP) for strength gains. Twenty men (age = 21 +/- 2.3 years) were randomly assigned to LP (n = 10) or DUP (n = 10) groups. One repetition maximum (1RM) was recorded for bench press and leg press as a pre-, mid-, and posttest. Training involved 3 sets (bench press and leg press), 3 days per week. The LP group performed sets of 8 RM during weeks 1-4, 6 RM during weeks 4-8, and 4 RM during weeks 9-12. The DUP group altered training on a daily basis (Monday, 8 RM; Wednesday, 6 RM; Friday, 4 RM). Analysis of variance with repeated measures revealed statistically significant differences favoring the DUP group between T1 to T2 and T1 to T3. Making program alterations on a daily basis was more effective in eliciting strength gains than doing so every 4 weeks.

Sale et al. (1990) conducted a study by alternating strength training on one day, with endurance training on the other and compared doing both types of training on the same days per week. Young men (N = 7) experienced strength and endurance training together for two days per week for 20 weeks. A second group (N = 8) performed strength and endurance work two days per week but on different days. Strength training consisted of six to eight bouts of 15-20 RM on a leg press machine. Endurance training consisted of six to eight 3-min bouts on a cycle ergometer at 90-100% VO2max. Both groups improved similarly in strength measures except that the strength-alone training significantly increased the leg press 1 RM more. The reactions to endurance training were similar between the groups with the exception of citrate synthase increased significantly more in the combined training group. Generally, there was little that differed between the groups indicating that the training volume was possibly too low to produce differentiation, although both groups did improve across the
duration of the study. Implication made by him was that the mixed and separate strength and endurance training has mainly similar training effects when the volume and frequency of training are low.

Newton, et al. (2006) conducted a study to evaluate whether a short period of ballistic resistance training would attenuate this loss. Fourteen collegiate women volleyball players were trained for 11 weeks with periodized traditional and ballistic resistance training. There was a 5.4% decrease in approach jump and reach height during the traditional training period (start of season to midseason), and a 5.3% increase during the ballistic training period (midseason to end of season), but values were not different from start to end of season. These changes in overall jump performance were reflective of changes in underlying neuromuscular performance variables: in particular, power output and peak velocity during loaded jump squats, countermovement jumps, and drop jumps. During the first 7 weeks of traditional heavy resistance training, it appears that the neuromuscular system is depressed, perhaps by the combination of training, game play, and skills practice precluding adequate recovery. Introduction of a novel training stimulus in the form of ballistic jump squats and reduction of heavy resistance training of the leg extensors stimulated a rebound in performance, in some cases to exceed the athlete’s ability at the start of the season. Periodization of in-season training programs similar to that used in this study may provide volleyball players with good vertical jump performance for the crucial end-of-season games.

Marx et al. (2001) investigated the long-term training adaptations associated with low-volume circuit-type versus periodized high-volume resistance training programs in women. 34 healthy, untrained women were
randomly placed into one of the following groups: low-volume, single-set circuit (SSC; N = 12); periodized high-volume multiple-set (MS; N = 12); or no exercising control (CON) group (N = 10). The SSC group performed one set of 8-12 repetitions to muscular failure 3 d x wk (-1). The MS group performed two to four sets of 3-15 repetitions with periodized volume and intensity 4 d x wk(-1). Muscular strength, power, speed, endurance, anthropometry, and resting hormonal concentrations were determined pre-training (T1), after 12 wk (T2), and after 24 wk of training (T3). The results of the study indicated that 1-RM bench press and leg press, and upper and lower body local muscular endurance increased significantly (P < or = 0.05) at T2 for both groups, but only MS showed a significant increase at T3. Muscular power and speed increased significantly at T2 and T3 only for MS. Increases in testosterone were observed for both groups at T2 but only MS showed a significant increase at T3. Cortisol decreased from T1 to T2 and from T2 to T3 in MS. Insulin-like growth factor-1 increased significantly at T3 for SSC and at T2 and T3 for MS. No changes were observed for growth hormone in any of the training groups. It was observed that significant improvements in muscular performance may be attained with either a low-volume single-set program or a high-volume, periodized multiple-set program during the first 12 wk of training in untrained women. However, dramatically different training adaptations are associated with specific domains of training program design which contrast in speed of movement, exercise choices and use of variation (periodization) in the intensity and volume of exercise.

Kraemer et al. (2000) examined 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.

Kraemer et al. (2003) compared the physiological and performance adaptations between periodized and non-periodized resistance training in women collegiate tennis athletes. Thirty women (19 +/- 1 yr) were assigned to either a periodized resistance training group (P), non-periodized training group (NV), or a control group (C). Assessments for body composition, anaerobic power, VO₂(max), speed, agility, maximal strength, jump height, tennis-service velocity, and resting serum hormonal concentrations were performed before and after 4, 6, and 9 months of resistance training.
performed 2-3 d.wk (-1). Nine months of resistance training resulted in significant increases in fat-free mass, anaerobic power, grip strength, jump height, one-repetition maximum (1-RM) leg press, bench press, and shoulder press, serve, forehand, and backhand ball velocities and resting serum insulin-like growth factor-1, testosterone, and cortisol concentrations. Percent body fat and VO₂ (max) decreased significantly in the P and NV groups after training. During the first 6 months, periodized resistance training elicited significantly greater increases in 1-RM leg press (9 +/- 2 vs 4.5 +/- 2%), bench press (22 +/- 5 vs 11 +/- 8%), and shoulder press (24 +/- 7 vs 18 +/- 6%) than the NV group. The absolute 1-RM leg press and shoulder press values in the P group were greater than the NV group after 9 months. Periodized resistance training also resulted in significantly greater improvements in jump height (50 +/- 9 vs. 37 +/- 7%) and serve (29 +/- 5 vs. 16 +/- 4%), forehand (22 +/- 3 vs. 17 +/- 3%), and backhand ball velocities (36 +/- 4 vs. 14 +/- 4%) as compared with non-periodized training after 9 months. The conclusion of the study demonstrated that periodization of resistance training over 9 months was superior for enhancing strength and motor performance in collegiate women tennis players.

2.2 STUDIES ON INFLUENCE OF RESISTANCE TRAINING VOLUME AND PERIODIZATION

According to Eric J Drinkwater (2006) Basketball is a sport with many complex demands that require a combination of fitness, skills, team tactics and strategies, and motivational aspects. However, key areas that are likely to play an important role in a Basketball player’s success are muscular strength, fitness and body size. Methods of evaluating and developing these characteristics have been extensively tested in controlled
research settings, but there is a dearth of research exploring the value of and methods of improving, muscular strength, fitness and body size of Basketball players within the demanding schedule of an elite junior development program. These were therefore explored in this thesis. Most high-level Basketball players participate in an organized resistance training program to improve muscular strength, fitness, and body size. Bench press is one of the most commonly performed resistance training exercises, and there are many different training philosophies revolving around manipulation of different components of the bench press mechanics. During the concentric movement of the bench press, there is an initial high-power push after chest contact, immediately followed by a characteristic area of low power, the so-called “sticking region”. During high-intensity lifting, this decline in power can result in a failed lift attempt. The purpose of this study was firstly to determine the validity of an optical encoder to measure power, and secondly to employ this device to determine power changes during the initial acceleration and “sticking region” during fatiguing repeated bench presses. Twelve highly trained junior Basketball players performed a free-weight bench press, a Smith Machine back squat, and a Smith Machine 40 kg bench press throw for power validation measures. All barbell movements were simultaneously monitored using videography and an optical encoder. Eccentric and concentric mean and peak power were calculated using time and position data derived from each method. Validity of power measures between the video (criterion) and optical encoder scores were evaluated by standard error of the estimate (SEE) and coefficient of variation (CV). Seven subjects then performed four sets of six bench press repetitions progressively increasing from 85 to 95% of their 6 repetition maximum, with each repetition continually monitored by an optical
encoder. The power SEE ranged from 3.6 to 14.4 W (CV. 1.0-3.0%; correlation, 0.97-1.00). During the bench press training, peak power declined by ~50% (p<0.05) during the initial acceleration phase of the final two repetitions of the final set. While decreases in peak power of the sticking point were significant (p<0.05) as early as repetition six (-42%) they reached critically low levels in the final two repetitions (~ -95%). In conclusion, the optical encoder provided valid measures of kinetics during free-weight resistance training movements. The decline in power during the initial acceleration phase appears a factor in a failed lift attempt in the sticking point in highly trained junior Basketball players. Study 4 The power loss in the first phase of the bench press only becomes a limiting factor when the loss of power in the sticking point leads to lift failure. Therefore, training to the point of failure may be an important stimulus for generating sufficient power in the first phase of the bench press to successfully press through the sticking point. This study investigated the importance of training leading to repetition failure in optimizing the performance of elite junior athletes in two different tests: six repetition maximum (6RM) bench press strength and 40kg bench throw power. Subjects were 26 elite junior male basketball (n=12, age 18.6 ± 0.3 y, height 202.0 ± 11.6 cm, mass 97.0 ± 12.9 kg) and soccer (n=14, age 17.4 ± 0.5 y, height 179.0 ± 7.0 cm, mass 75.0 ± 7.1 kg) players with a history of greater than six months strength training. Subjects were initially tested twice for 6RM bench press mass and 40kg Smith Machine bench throw power output (W) to establish retest reliability. Subjects then undertook bench press training three sessions per week for six weeks, using equal volume programs (24 total repetitions x 80-105% 6RM in 13 min 20 s). Subjects were assigned to one of two experimental groups designed to either elicit
repetition failure with four sets of six repetitions every 260 s (RF4x6) or allow all repetitions to be completed with eight sets of three repetitions every 113 s (NF8x3). The RF4x6 treatment elicited substantial increases in strength (7.3 ± 2.4kg, +9.5%, p<0.001) and power (40.8 ± 24.1 W, +10.6%, p<0.001), while the NF8x3 group elicited 3.6 ± 3.0kg (+5.0%, p<0.005) and 25 ±19.0 W increases (+6.8%, p<0.001). The improvements in the RF4x6 group were significantly greater than the repetition rest group for both strength (p<0.01) and power (p<0.05). Bench press training that leads to repetition failure induces greater strength gains than non-failure training in the bench press exercise for elite junior team sport athletes. Study 5 Strength improvements are greater when resistance training continues to the point where the individual cannot perform additional repetitions (i.e. repetition failure). Performing additional forced repetitions after the point of repetition failure to further increase the set volume is a common resistance training practice. However, whether increasing the number of forced repetitions increases the magnitude of strength development is unknown and was investigated here. Twenty-two team-sport athletes trained for six weeks completing either 4x6, 8x3, or 12x3 (sets x repetitions) of bench press. The 4x6 and 12x3 protocols increased the number of forced repetitions by respectively increasing work intervals or volume compared to the 8x3 group. Subjects were tested on 3- and 6-repetition maximum (RM) bench press (81.7±9.9 and 76.2±9.2 kg respectively, mean ±SD), and 40kg Smith Machine bench press throw power (756±156 W). The 4x6 and 12x3 groups had more forced repetitions per session (p<0.01) than the 8x3 group (4.4±0.9 and 3.6±0.8, and 2.0±0.5 repetitions). As expected, all groups improved 3RM (4.6 kg, 95% Confidence Limits: 3.2-6.1), 6RM (4.9 kg, 3.3-6.5), bench throw peak power (59 W, 23-95), and mean power (23 W.
There were no significant differences in strength or power gains between groups. In conclusion, when repetition failure was reached, neither additional forced repetitions, nor additional set volume further improved the magnitude of strength gains. This finding questions the efficacy of these current common strength-training practices. Finally they concluded that the quality of key fitness and anthropometric test scores of Australian junior Basketball players showed evidence of decline over a 7 year study period despite the importance of fitness and body composition to Basketball. Fortunately, there is sufficient individual variation in changes in fitness and anthropometry test scores to indicate that substantial improvements are possible with an appropriate training program. As a method of improving fitness, the bench-press resistance training model, consisting of two separate six-week training programs equal in volume and training time but differing in the amount of fatigue, showed that training to the point of repetition failure elicited greater strength adaptations than non-failure training. Refinement of the training protocol allowed further comparison of the effects of additional training volume and a greater number of forced repetitions. Taken together these experimental findings support the notion that training to the point of repetition failure is an important component of a periodized training program for strength development. However six weeks of training using forced repetitions with the assistance of a spotter conveyed no further benefit to strength, power, or hypertrophic adaptations. He stressed future research to verify whether the transfer of these upper body adaptations apply to lower-body activities such as squats, and whether high intensity short term strength and conditioning programs can improve power output enough to have a substantial positive impact on Basketball-specific skills such as running and jumping.
Willardson (2006) conducted a study on the factors affecting the length of the rest interval between resistance exercise sets. Research has indicated that multiple sets are superior to single sets for maximal strength development. However, whether maximal strength gains are achieved may depend on the ability to sustain a consistent number of repetitions over consecutive sets. A key factor that determines the ability to sustain repetitions is the length of rest interval between sets. The length of the rest interval is commonly prescribed based on the training goal, but may vary based on several other factors. The purpose of this review was to discuss these factors in the context of different training goals. When training for muscular strength, the magnitude of the load lifted is a key determinant of the rest interval prescribed between sets. For loads less than 90% of 1 repetition maximum, 3–5 minutes rest between sets allows for greater strength increases through the maintenance of training intensity. However, when testing for maximal strength, 1–2 minutes rest between sets might be sufficient between repeated attempts. When training for muscular power, a minimum of 3 minutes rest should be prescribed between sets of repeated maximal effort movements (e.g., plyometric jumps). When training for muscular hypertrophy, consecutive sets should be performed prior to when full recovery has taken place. Shorter rest intervals of 30–60 seconds between sets have been associated with higher acute increases in growth hormone, which may contribute to the hypertrophic effect. When training for muscular endurance, an ideal strategy might be to perform resistance exercises in a circuit, with shorter rest intervals (e.g., 30 seconds) between exercises that involve dissimilar muscle groups, and longer rest intervals (e.g., 3 minutes) between exercises that involve similar muscle groups. In summary, the length of the rest interval between sets is only 1 component of
a resistance exercise program directed toward different training goals. Prescribing the appropriate rest interval does not ensure a desired outcome if other components such as intensity and volume are not prescribed appropriately.

Matuszak et al. (2003) examined the effects of different rest intervals on the repeatability of 1 repetition maximum (1RM) efforts in the free-weight back squat exercise, 17 weight-trained men served as subjects (mean age 22.0 years). One repetition maximum was tested on each of the first 2 days of testing to establish a stable baseline (1RM = 184.9 kg). Each of the next 3 sessions involved performing 2 1RM back squats, with the rest interval between attempted lifts being either 1, 3, or 5 minutes, assigned in a counterbalanced fashion. For the 1-minute rest interval, 13 of 17 subjects successfully completed the second lift; for the 3-minute rest interval, 16 of 17 were successful; and for the 5-minute rest interval, 15 of 17 were successful. Cochran Q analysis determined no significant difference (p > 0.05) in the ability to repeat a successful maximal-effort back squat when different rest intervals were used. These findings are consistent with the literature for the bench-press exercise and indicate that 1-minute rest intervals are sufficient for recovery between attempted lifts during 1RM testing or training for the free-weight back squat when involving lifters of this caliber.

Campos et al. (2002) investigated the "strength-endurance continuum". Thirty-two untrained men [mean (SD) age 22.5 (5.8) years, height 178.3 (7.2) cm, body mass 77.8 (11.9) kg] participated in an 8-week progressive resistance-training program to the subjects who were divided into four groups: a low repetition group (Low Rep, n = 9) performing 3-5
repetitions maximum (RM) for four sets of each exercise with 3 min rest between sets and exercises, an intermediate repetition group (Int Rep, n = 11) performing 9-11 RM for three sets with 2 min rest, a high repetition group (High Rep, n = 7) performing 20-28 RM for two sets with 1 min rest, and a non-exercising control group (Con, n = 5). Three exercises (leg press, squat, and knee extension) were performed 2 days/week for the first 4 weeks and 3 days/week for the final 4 weeks. Maximal strength [one repetition maximum, 1RM], local muscular endurance (maximal number of repetitions performed with 60% of 1RM), and various cardio respiratory parameters (e.g., maximum oxygen consumption, pulmonary ventilation, maximal aerobic power, time to exhaustion) were assessed at the beginning and end of the study. In addition, pre- and post-training muscle biopsy samples were analyzed for fibre-type composition, cross-sectional area, myosin heavy chain (MHC) content, and capillarization. Maximal strength improved significantly more for the Low Rep group compared to the other training groups, and the maximal number of repetitions at 60% 1RM improved the most for the High repetitions group. In addition, maximal aerobic power and time to exhaustion significantly increased at the end of the study for only the High repetition group. All three major fibre types (types I, IIA, and IIB) hypertrophied for the Low Rep and Int repetitions groups, whereas no significant increases were demonstrated for either the High repetitions or Con groups. However, the percentage of type IIB fibres decreased, with a concomitant increase in IIAB fibres for all three resistance-trained groups. These fibre-type conversions were supported by a significant decrease in MHCIIb accompanied by a significant increase in MHCIIa. No significant changes in fibre-type composition were found in the control samples. Although all three training regimens resulted in similar
fibre-type transformations (IIB to IIA), the low to intermediate repetition resistance-training programs induced a greater hypertrophic effect compared to the high repetition regimen. The High repetitions group, however, appeared better adapted for sub maximal, prolonged contractions, with significant increases after training in aerobic power and time to exhaustion. Thus, low and intermediate RM training appears to induce similar muscular adaptations, at least after short-term training in previously untrained subjects. Overall, however, these data demonstrate that both physical performance and the associated physiological adaptations are linked to the intensity and number of repetitions performed, and thus lend support to the "strength-endurance continuum".

Sporer and Wenger (2003) conducted a study to determine if the type and intensity of aerobic training affects performance in a subsequent strength-training session after varying periods of recovery. Sixteen male subjects participated in the study and were divided into 2 groups based on aerobic training, high-intensity intervals (MAX n = 8) and continuous submaximal (SUB n = 8). Each subject performed 4 sets of both bench press and leg press at approximately 75% 1 repetition maximum (1RM) following aerobic training with recovery periods of 4, 8, and 24 hours, as well as once in a control condition. Both the 4- and 8-hour conditions resulted in fewer total leg press repetitions than the control and 24-hour conditions. There was no difference between both the control and 24-hour conditions. No main effect was shown with respect to the type of aerobic training. It was concluded that when aerobic training precedes strength training, the volume of work that can be performed is diminished for up to 8 hours. This impairment appeared to be localized to the muscle groups involved in the aerobic training.
Paulsen et al. (2003) made an investigation to compare the effects of single-set strength training and 3-set strength training during the early phase of adaptation in 18 untrained male subjects (age, 20-30 years). After initial testing, subjects were randomly assigned to either the 3L-1U group (n = 8), which trained 3 sets in leg exercises and 1 set in upper-body exercises, or the 1L-3U group (n = 10), which trained 1 set in leg exercises and 3 sets in upper-body exercises. Testing was conducted at the beginning and at the end of the study and consisted of 2 maximal isometric tests (knee extension and bench press) and 6 maximal dynamic tests (1 repetition maximum [1RM] tests). Subjects trained 3 days per week for 6 weeks. After warm-up, subjects performed 3 leg exercises and 4 upper-body exercises. In both groups, each set consisted of 7 repetitions (reps) with the load supposed to induce muscular failure after the seventh rep (7RM load). After 6 weeks of training, 1RM performance in all training exercises was significantly increased (10-26%, p < 0.01) in both groups. The relative increase in 1RM load in the 3 leg exercises was significantly greater in the 3L-1U group than in the 1L-3U group (21% vs. 14%, p = 0.01). However, the relative increase in 1RM load in the 3 upper-body exercises was similar in the 3L-1U group (16%) and the 1L-3U group (14%). These results showed a superior adaptation to 3-set strength training, compared with 1-set strength training, in leg exercises but not in upper-body exercises during the early phase of adaptation.

Parker et al (1996) studied the effects of strength training on cardiovascular responses during a sub maximal walk and weight-loaded walking test in older females. After 16 weeks of weight training women aged 60-77 showed reduced heart rate, systolic blood pressure, and rate pressure product while treadmill walking with and without a weight load of
40% bodyweight. They concluded that strength training reduces cardiovascular stress during daily tasks in healthy older women.

Kerr et al (1996) conducted a study to find out the exercise effects on bone mass in postmenopausal women are site-specific and load-dependent. Fifty-six (56) subjects were randomized to either heavy or light resistance training. Only resistance training that involved heavier loads increased bone mineral density.

Williford et al. (1994) conducted an investigation to determine the performance and physiologic characteristics of a "successful" American high school football team and to compare the present values with values reported for other groups of high school, college, and professional players. For descriptive purposes, players were divided into two groups: backs (N = 8) and linemen (N = 10). Maximal aerobic power (VO2max) was determined from a maximal treadmill test, and body composition was evaluated by hydrostatic weighing. Maximal strength values were evaluated by one-repetition maximum bench press and squat test; the sit-and-reach test was used to measure flexibility. Speed and power were evaluated by a vertical jump and a 36.6-meter sprint. His results indicated that compared with other groups of college and professional players, as the level of competition increases so do height, weight, and fat-free weight of the players. Similar maximum oxygen consumption values were found for the present group when compared with other groups of these players. From the strength and power standpoint, football players at all levels are becoming stronger. Incorporation of strength training programs has greatly improved strength and performance profiles of football players at all levels of competition.
Braith et al. (1989) evaluated the effectiveness of resistance training performed either 2 days/week or 3 days/week. One hundred and seventeen sedentary volunteers were randomly assigned to one of the two training groups or a control group. Twenty-two men (27 +/- 5 years) and 22 women (26 +/- 5 years) trained for 10 weeks. Twenty-five men (26 +/- 5 years) and 22 women (24 +/- 5 years) trained for 18 weeks. Twenty-six subjects served as controls and did not train. Training consisted of a single set of variable resistance bilateral knee extensions performed to volitional fatigue with a weight load that allowed seven to ten repetitions. Prior to and immediately following training, isometric strength was evaluated at 70, 85, 100, 115, 130, 145, 160, and 171 degrees of knee extension with a Nautilus knee extension tensiometer. All groups who trained showed a significant increase in peak isometric strength when compared with controls (P less than 0.01). Groups that trained 3 days/week increased peak isometric strength (10 weeks = 21.2%; 18 weeks = 28.4%) to a greater extent (P less than 0.05) than groups that trained 2 days/week (10 weeks = 13.5%; 18 weeks = 20.9%). They concluded that resistance training 2 days/week significantly improves knee extension isometric strength; however, the magnitude of strength gain is greater when training is performed 3 days/week. These data indicated that the adult exerciser (18 to 38 years) training 2 days/week may derive approximately 80% of the isometric strength benefits achieved by those training 3 days/week.

Westcott (2001) assessed a way to increase the intensity and effectiveness of resistance training by comparing training with a slower repetition speed to training with a conventional repetition speed. Slower repetition speed may effectively increase intensity throughout the lifting phase while decreasing momentum. Two studies were done with untrained
men (N=65) and women (N=82), (mean age=53.6) who trained two to three times per week for eight to 10 weeks on a 13 exercise Nautilus circuit performing one set of each exercise. Participants exclusively trained using regular speed repetitions for 8 to 12 repetitions per set at 7 sec each (2 sec lifting, 1 sec pause, 4 sec lowering) or a Super Slow training protocol where they completed 4 to 6 repetitions per set at 14 sec each (10 sec lifting, 4 sec lowering). All of the participants were tested for either the 10 repetition-maximum (RM) weight load (regular-speed group) or the 5-RM weight load (slow-speed group). In both the studies, Super-Slow training resulted in about a 50% greater increase (p<0.001) in strength for both men and women than regular speed training. In Study 1, the Super-Slow training group showed a mean increase of 12.0 kg and the regular speed group showed an increase of 8.0 kg increase (p<0.001). In Study 2, the Super-Slow training group showed a 10.9 kg increase and the regular speed group showed an increase of 7.1 kg (p<0.001). They concluded that Super-Slow training is an effective method for middle-aged and older adults to increase strength. Although studies still need to be done with at-risk populations, repetition speed should be considered when prescribing resistance training.

Westcott, et al. (2001) studied on strength exercises that were performed slowly and at "regular" speeds were evaluated for intensity and effectiveness. Two studies were performed; one with untrained males (N = 65) and females (N = 82). Training was experienced two to three times per week for eight to ten weeks performing one set of each of 13 Nautilus exercises. Regular repetitions were 8-12 at 7 seconds each (2 s lifting, 1 s pause, 4 s lowering). Super slow repetitions were 4-6 repetitions at 14 seconds each (10 s lifting, 4 s lowering). In both the studies, super-slow training resulted in ~50% greater increase in strength than regular speed
training, although both groups demonstrated significant strength gains. His implication was that the super-slow strength training should be considered when a conditioning muscle structure is the aim of exercising.

Keeler et al. (2001) performed a randomized exercise training study to assess the effects of traditional Nautilus-style (TR) or superslow (SS) strength training on muscular strength, body composition, aerobic capacity, and cardiovascular endurance. Subjects were 14 healthy, sedentary women, 19-45 years of age (mean +/- SD age, 32.7 +/- 8.9 years), randomized to either the SS or TR training protocols and trained 3 times per week for 10 weeks. Measurements were taken both before and after training, which included a maximal incremental exercise test on a cycle ergometer, body composition, and 1 repetition maximum (1RM) tests on 8 Nautilus machines. Both groups increased their strength significantly on all 8 exercises, whereas the TR group increased significantly more than the SS group on bench press (34% vs. 11%), torso arm (anterior lateral pull-down) (27% vs. 12%), leg press (33% vs. 7%), leg extension (56% vs. 24%), and leg curl (40% vs. 15%). Thus, the TR group's improvement in total exercise weight lifted was significantly greater than that of the SS group after testing (39% vs. 15%). Exercise duration on the cycle ergometer and work rate significantly improved for both groups, but there was no group-by-training interaction. No significant differences were found for body composition or additional aerobic variables measured. Both strength training protocols produced a significant improvement in strength during a 10-week training period, but the TR protocol produced better gains in the absence of changes in percentage of body fat, body mass index, lean body mass, and body weight. In addition, strength training alone did not improve VO₂max, yet short-term endurance increased.
Blount, et al (2003) assigned College-age males (N = 39) to a traditional exercise (ACSM recommended), super slow, and control (no formal activity) training condition for 16 weeks. Super slow training represents a high-intensity, low velocity resistance program and consequently, should be expected to improve strength related factors. Super slow improved upper limb muscle endurance and lower limb muscle strength. Traditional training did not improve those features. Thus the implication made by him was that super slow training improves strength related factors.

Christou et al. (2006) examined the effects of a progressive resistance-training program in addition to soccer training on the physical capacities of male adolescents. Eighteen soccer players (age: 12–15 years) were separated in a soccer (SOC; n = 9) and a strength-soccer (STR; n = 9) training group and 8 subjects of similar age constituted a control group. All players followed a soccer training program 5 times a week for the development of technical and tactical skills. In addition, the STR group followed a strength training program twice a week for 16 weeks. The program included 10 exercises, and at each exercise, 2–3 sets of 8–15 repetitions with a load 55–80% of 1 repetition maximum (1RM). Maximum strength ([1RM] leg press, bench-press), jumping ability (squat jump [SJ], counter movement jump [CMJ], repeated jumps for 30 seconds) running speed (30 m, 10 × 5-m shuttle run), flexibility (seat and reach), and soccer technique were measured at the beginning, after 8 weeks, and at the end of the training period. After 16 weeks of training, 1RM leg press, 10 × 5-m shuttle run speed, and performance in soccer technique were higher (p < 0.05) for the STR and the SOC groups than for the control group. One repetition maximum bench press and leg press, SJ and CMJ height, and 30-
m speed were higher (p < 0.05) for the STR group compared with SOC and control groups. The above data show that soccer training alone improves more than normal growth maximum strength of the lower limps and agility. The addition of resistance training, however, improves more maximal strength of the upper and the lower body, vertical jump height, and 30-m speed. Thus, the combination of soccer and resistance training could be used for an overall development of the physical capacities of young boys.

2.3 STUDIES ON EFFECTS OF RESISTANCE TRAINING ON WOMEN’S STRENGTH POWER AND OCCUPATIONAL PERFORMANCES

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

O'Hagan et al. (1995) studied the response towards the resistance training in young women and men. Six women and 6 men trained the elbow flexors 3 days per week for 20 wks, one arm performing in each session 3 5 sets of 10 maximal concentric actions on an accommodating resistance device, the other arm 3 5 sets of 8 12 coupled eccentric/concentric actions on a weight training device. With results collapsed across the two training modes, the women made significantly (p less than 0.05) greater relative increases than men in strength measured on the weight (116 vs. 46 percent) and accommodating (99 vs. 46 percent) resistance devices, and greater absolute (3.5 vs. 1.3 N.m) and relative (13.7 vs. 3.2 percent) increases in strength measured on an isokinetic dynamometer. Absolute (cm2) and relative (percent) biceps, brachialis, and total elbow flexor cross sectional area (from CT scans) increased significantly, however, the women's vs.
men's respective relative and absolute increases did not differ significantly: biceps (13 vs. 7 percent, 0.9 vs. 1.0 cm²), brachialis (53 vs. 31 percent, 2.1 vs. 2.3 cm²), and total (26 vs. 15 percent, 3.1 vs. 3.3 cm²) flexor area. Biceps type I and II fiber area, and the II/I area ratio did not increase significantly. The data indicate that in response to the same short-term training program, muscle size increases similarly in women and men but women make greater relative increases in strength.

2.4 STUDIES ON RESISTANCE-TRAINING REGIMENS WITH VARIED COMBINATIONS OF LOW, MODERATE AND HIGH INTENSITY EXERCISES.

Gonzalez-Badillo et al. (2005) examined the effects of 3 resistance training volumes on maximal strength in the snatch (Sn), clean and jerk (CandJ), and squat (Sq) exercises during a 10-week training period. Fifty-one experienced (>3 years), trained junior lifters were randomly assigned to one of 3 groups: a low-volume group (LVG, n = 16), a moderate-volume group (MVG, n = 17), and a high-volume group (HVG, n = 18). All subjects trained 4-5 days a week with a periodized routine using the same exercises and relative intensities but a different total number of sets and repetitions at each relative load: LVG (1,923 repetitions), MVG (2,481 repetitions), and HVG (3,030 repetitions). The training was periodized from moderate intensity (60-80% of 1 repetition maximum [1RM]) and high number of repetitions per set (2-6) to high intensity (90-100% of 1RM) and low number of repetitions per set (1-3). During the training period, the MVG showed a significant increase for the Sn, CandJ, and Sq exercises (6.1, 3.7, and 4.2%, respectively, p < 0.01); whereas in the LVG and HVG, the increase took place only with the CandJ exercise (3.7 and 3%, respectively, p < 0.05) and the Sq exercise (4.6%, p < 0.05, and 4.8%, p <
The increase in the Sn exercise for the MVG was significantly higher than in the LVG (p = 0.015). Calculation of effect sizes showed higher strength gains in the MVG than in the HVG or LVG. There were no significant differences between the LVG and HVG training volume-induced strength gains. The present results indicate that junior experienced lifters can optimize performance by exercising with only 85% or less of the maximal volume that they can tolerate. These observations may have important practical relevance for the optimal design of strength training programs for resistance-trained athletes, since we have shown that performing at a moderate volume is more effective and efficient than performing at a higher volume.

Donnelly et al (2003) examined the long-term effects of a supervised program of moderate-intensity exercise on body weight and composition in previously sedentary, overweight and moderately obese men and women. He hypothesized that a 16-month program of verified exercise would prevent weight gain or provides weight loss in the exercise group compared with controls. Participants were recruited from 2 midwestern universities and their surrounding communities. One hundred thirty-one participants were randomized to exercise or control groups, and 74 completed the intervention and all laboratory testing. Exercise was supervised, and the level of energy expenditure of exercise was measured. Controls remained sedentary. From the results he concluded that moderate-intensity exercise sustained for 16 months is effective for weight management in young adults.

Abe et al (2003) examined the absolute and relative changes in skeletal muscle (SM) size using whole body magnetic resonance imaging.
(MRI) in response to heavy resistance training (RT). For this three young men trained three days a week for 16 weeks. MRI measured total SM mass and fat free mass (FFM) had increased by 4.2 kg and 2.6 kg respectively after resistance training. From the results he concluded that RT induces larger increases in SM mass than in FFM. RT induced muscle hypertrophy does not occur uniformly throughout each individual muscle or region of the body. Therefore the distribution of muscle hypertrophy and total SM mass are important for evaluating the effects of total body RT on muscle size.

Goto et al. (2004) studied the acute and long-term effects of resistance-training regimens with varied combinations of high- and low-intensity exercises. Acute changes in the serum growth hormone (GH) concentration were initially measured after 3 types of regimens for knee extension exercise. They were: a medium intensity (approximately 10 repetition maximum [RM]) short interset rest period (30 s) with progressively decreasing load ("hypertrophy type"); 5 sets of a high-intensity (90% of 1RM) and low-repetition exercise ("strength type"); and a single set of low-intensity and high-repetition exercise added immediately after the strength-type regimen ("combi-type"). Post exercise increases in serum GH concentration showed significant regimen dependence: hypertrophy-type > combi-type > strength-type (p < 0.05, n = 8). Next, the long-term effects of periodized training protocols with the above regimens on muscular function were investigated. Male subjects (n = 16) were assigned to hypertrophy/combi (HC) or hypertrophy/strength (HS) groups and performed leg press and extension exercises twice a week for 10 weeks. During the first 6 weeks, both groups used the hypertrophy-type regimen to gain muscular size. During the subsequent 4 weeks, HC and HS groups performed combi-type and strength-type regimens, respectively. Muscular
strength, endurance, and cross sectional area (CSA) were examined after 2, 6, and 10 weeks. After the initial 6 weeks, no significant difference was seen in the percentage changes of all variables between the groups. After the subsequent 4 weeks, however, 1RM of leg press, maximal isokinetic strength, and muscular endurance of leg extension showed significantly (p < 0.05) larger increases in the HC group than in the HS group. In addition, increases in CSA after this period also tended to be larger in the HC group than in the HS group (p = 0.08). It was finalized that a combination of high- and low-intensity regimens is effective for optimizing the strength adaptation of muscle in a periodized training program.

Borst, S., et al (1998) attempted to determine the effects of resistance training on IGF-I and IGF binding protein (IGFBP-3) since there are equivocal research findings concerning the relationship between physical activity and circulating insulin-like growth factor (IGF-I). Ss (N = 11) participated in 25-week resistance training programs of low- (1 set) or high-volume (3 sets). Blood was sampled pre-, mid- (13 weeks), and post-training. IGF-I increased similarly with both training intensities (34% low; 30% high). However, IGFBP-3 increased slightly but not significantly in both groups. He concluded that the resistance training increases IGF-I irrespective of training intensity and IGFBP-3 is unaffected by resistance training.

2.5 STUDIES ON INFLUENCE OF RESISTANCE TRAINING ON PHYSICAL, PHYSIOLOGICAL AND PERFORMANCE ADAPTATIONS

Ángyán et al. (2003) investigated the importance of the athlete's motor capabilities in success in sport. More precisely, the association of
anthropometrical and physiological attributes, as well as motor abilities of elite Basketball players with plays elements of Basketball. The subjects were seven elite Basketball players. At the end of the competitive season, the anthropometrical and physiological features were measured to establish the physical fitness of the subjects. Both general and sport-specific motor tests were done. The coach estimated the performance of each player during the games of the competitive season. The coach's data sheet incorporated 14 parameters of the game. Regression analyses indicated significant correlation between certain variables of the laboratory tests and the data of the coach's estimation statistics. Knowing these relationships provides us with valuable predictive information about player's capabilities in sport.

Sallet et al. (2005) investigated the physical and physiological characteristics of different first and second division professional Basketball players, and to relate them to playing position and level of play. A total of 58 players were divided into Pro-A and Pro-B groups and were assessed for physical characteristics, maximal treadmill test and a 30 s all-out test. The sample included 22 centers, 22 forwards and 14 guards. Of these the centers were significantly taller and heavier (203.9±5.3 cm and 103.9±12.4 kg) than forwards (195.8±4.8 cm and 89.4±7.1 kg) and guards (185.7±6.9 and 82±8.8 kg) and also had higher body fat percentages than the other groups. Forwards were also significantly taller than guards. Centers presented a lower maximal aerobic velocity (km.h⁻¹) than guards (15.5±1.2 vs 16.8±1.5, P<0.05) on the maximal treadmill test and a lower maximal velocity (rpm) than forwards (156.5±18.4 vs 170.3±18.3, P<0.05) on the 30 s all-out test. VO₂max (ml.min⁻¹ kg⁻¹) was significantly lower for ProA (53.7±6.7) compared to ProB (56.5±7.7) players and the fatigue index on the 30 all-out test was higher for the ProA group (P<0.05). It was
concluded that many physical differences, most notably size, exists between players as a function of their playing position. But these differences have no relationship to the level of play of professional players. General aerobic capacity is fairly homogeneous between playing position and level of play, even if there are observable VO$_2$max differences due to inter-individual profiles. On the other hand, anaerobic capacity seems to be a better predictor of playing level even though it is not clear whether such capacity comes from specific training in ProA, or from initial selection criteria.

Kraemer et al. (2004) examined the adaptations of arm and thigh muscle hypertrophy to different long-term periodized resistance training programs and the influence of upper body resistance training. Eighty-five untrained women (mean age = 23.1 +/- 3.5 yr) started in one of the following groups: total-body training [TP, N = 18 (3-8 RM training range) and TH, N = 21 (8-12 RM training range)], upper-body training [UP, N = 21 (3-8 RM training range) and UH, N = 19, (8-12 RM training range)], or a control group (Control, N = 6). Training took place on three alternating days per week for 24 wk. Assessments of body composition, muscular performance, and muscle cross-sectional area (CSA) via magnetic resonance imaging (MRI) were determined pre-training (T1), and after 12 (T2) and 24 wk (T3) of training. Results of the study were: arm cross-sectional area increased at T2 (approximately 11%) and T3 (approximately 6%) in all training groups and thigh CSA increased at T2 (approximately 3%) and T3 (approximately 4.5%) only in TP and TH. Squat one-repetition maximum (1 RM) increased at T2 (approximately 24%) and T3 (approximately 11.5%) only in TP and TH and all training groups increased 1 RM bench press at T2 (approximately 16.5%) and T3 (approximately 12.4%). Peak power produced during loaded jump squats increased from T1
to T3 only in TP (12%) and TH (7%). Peak power during the ballistic bench press increased at T2 only in TP and increased from T1 to T3 in all training groups. Finally, he concluded that training specificity was supported (as sole upper-body training did not influence lower-body musculature) along with the inclusion of heavier loading ranges in a periodized resistance-training program. This may be advantageous in a total conditioning program directed at development of muscle tissue mass in young women.

Chilibeck et al. (1998) conducted a study to measure the degree to which muscle hypertrophy contributes to gains in strength during exercises of varying complexity. Nineteen young women resistance trained twice a week for 20 weeks, performing exercises designed to provide whole-body training. The lean mass of the trunk, legs and arms was measured by dual energy x-ray absorptiometry and compared to strength gains (measured as the 1-repetition maximum) in bench press, leg press and arm curl exercises, pre-, mid- (10 weeks) and post-training. No changes were found in a control group of ten women. For the exercise group, increases in bench press, leg press and arm curl strength were significant from pre- to mid-, and from mid- to post-training (P < 0.05). In contrast, increases in the lean mass of the body segments used in these exercises followed a different pattern. Increases in the lean mass of the arms were significant from pre- to mid-training, while increases in the lean mass of the trunk and legs were delayed and significant from mid- to post-training only (P < 0.05). It is concluded that a more prolonged neural adaptation related to the more complex bench and leg press movements may have delayed hypertrophy in the trunk and legs. With the simpler arm curl exercise, early gains in strength were accompanied by muscle hypertrophy and, presumably, a faster neural adaptation.