II. REVIEW OF THE RELATED LITERATURE

In general literature survey has served as guideline to identify the general trends of the present study. Since effective research is based upon past knowledge this review helps to do much better. The salient aspects related to study are briefly discussed under this chapter.

2.1. STUDIES ON ANAEROBIC POWER

Kasabalis et al (2005) evaluated the anaerobic power of elite male volleyball players, using the Wingate Anaerobic Test to examine the relationship between anaerobic powers and jumping performance. Athletes (n=56) and Non athletes (n=53) were divided into three age groups: Adults (18-25 yr.), juniors (15-16 yr.), and Youth (10-11 yr.). Measurements of height, body mass, vertical jump and Wingate scores indicated higher values for athletes. The specific training effects of anaerobic power were more pronounced at the age of 10-11 years than for Non athletes. A significant correlation coefficient between peak power and vertical jump was found for Athletes (r=.86) and for the total group (r=.82). These results indicated that vertical jump may predict the maximal anaerobic power and could be used by coaches as a practical and easy-to-apply field screening test for evaluation in volleyball training.

Bhanot and Sidhu (1989) conducted a study on maximal anaerobic power of Indian Players. The comparative study on aerobic power of different sports was conducted using 99 National Senior as well as National Junior players who were specialized in hockey and football (field games) volleyball and basketball, (court games). The maximal anaerobic power of the players was determined from maximal vertical velocity and body weight by the methods of Margaria. The football players have been found to be highest followed by hockey, volleyball and basketball players in vertical velocity. It is observed that field game players are higher than the court game players in vertical velocity and that volleyball players possess higher maximum anaerobic power than football, hockey and basketball players. In volleyball players, peak power was
underestimated using the three equations (1246+/-78 W, p<10(-4); 4314+/-216 W, p<0.001; 4607+/-251, p<0.005; for the Lewis, Harman and Sayers equations, respectively, versus 5355+/-522 W for the force platform). The results of the present study demonstrate the difficulty in choosing the most relevant equation in the jump power calculation.

2.2. STUDIES ON RESISTANCE TRAINING

INTRODUCTION

It has long been accepted that weight training (and the right strength training program) can improve performance for aerobic athletes. But it’s crucial to select the right exercises, perform them at the right intensity and place them within a progressive and carefully structured weights program. The method of how to weight train for explosive power was highlighted by the two leading sports coaches: Olympic rowing coach, Terry O'Neil, and Charles van Commenee, UK Athletics' multi-events and jumps coach on their titled of ‘inside secrets’.

O’Neil describes a weight training program that mirrors his athletes' race requirements as closely as possible. Crucially, he also explains how to structure the program within a 6-week training micro cycle so as to maximize the sports-specific transference of speed and power and avoid what he calls "physiological confusion" i.e. targeting two different physiological goals at the same time. Then, UK Athletics coach Charles van Commenee sets out the principles underlying his weight training techniques for achieving explosive power. He explains his training methodology in terms of hormonal response to the overload situation, and explains the importance both of exercise relevance and recovery (http://www.pponline.co.uk/prewp/aweber-speedwith.html)

Kraemer et al (2001) conducted a study on effect of resistance training on women's strength/power and occupational performances. For which they examined the strength, power, and military occupational task performances in
women. 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. Specific training programs resulted in significant increases in body mass (TP), 1-RM squat (TP, TH, FLD), bench press (all except AER), high pull (TP), squat jump (TP, TH, FLD), bench throw (all except AER), squat endurance (all except AER), 1-RM box lift (all except aerobic), repetitive box lift (all), push-ups (all except AER), sit-ups (all except AER), and 2-mile run (all). 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.

Wilson et al (1993) compared the effects of 10 wk of training with traditional back squats or one of two forms of plyometric training–loaded jump squats or drop jumps–on vertical jump performance. Two types of vertical jump tests were performed: 1) a counter-movement jump in which the subjects started from a standing position, performed a rapid crouch, and then jumped for maximal height, and 2) a jump from a static crouching position, i.e., with no counter movement. All training groups except the drop-jump group produced significant increases in vertical jump performance. For the counter-movement jump, the group that trained with loaded jump squats produced the greatest improvement (18%), which was significantly greater than that for the drop-jump
group (10%) or for the weight-trained group (5%). For the static crouch jump, the group trained with loaded jump squats increased jump height by 15%, which was significantly greater than the increase for the drop-jump group (7.2%) and for the weight training group (6.8%). These results were similar to those obtained by Berger (1963), who also found that training with jump squats loaded at 30% of maximum resulted in greater increases in vertical jump than did training programs consisting of traditional weight training, drop-jump training, or isometric training.

Elliott et al (1989) studied on the effect of weight training and plyometric on vertical jump ability. From the results he has concluded that the traditional weight training increases vertical jump performance, but not to the same extent as plyometric training with loaded jump squats. He gave explanation for the smaller effect of weight training is that the weight being lifted is decelerating for a considerable proportion of the movement On the other hand; plyometric training by drop jumping or by per-forming weighted jump squats allows athletes to use "compensatory acceleration" whereby they can complete the entire movement at high velocity (Hatfield, 1989). In comparing heavy weight training with the use of lighter weight and explosive jumps, most studies have found the latter to be more effective (Hakkinen & Komi, 1985b; Komi et al., 1982; Wilson et al., 1993).

Newton et al (1999) conducted a study on the effects of ballistic training on preseason preparation of elite volleyball players. The purpose of this study was to determine whether ballistic resistance training would increase the vertical jump (VJ) performance of already highly trained jump athletes. Sixteen male volleyball players from a NCAA division I team participated in the study. A Vertex was used to measure standing vertical jump and reach (SJR) and jump and reach from a three-step approach (AJR). Several types of vertical jump tests were also performed on a plyometric power system and a force plate to measure force, velocity, and power production during vertical jumping. The subjects completed the tests and were then randomly divided into two groups, control and treatment. All subjects completed the usual preseason volleyball on-
court training combined with a resistance training program. In addition, the treatment group completed 8 wk of squat jump training while the control group completed squat and leg press exercises at a 6RM load. Both groups were retested at the completion of the training period. The treatment group produced a significant increase in both SJR and AJR of 5.9+/−3.1% and 6.3+/−5.1%, respectively. These increases were significantly greater than the pre- to post changes produced by the control group, which were not significant for either jump. Analysis of the data from the various other jump tests suggested increased overall force output during jumping, and in particular increased rate of force development were the main contributors to the increased jump height. These results lend support to the effectiveness of ballistic resistance training for improving vertical jump performance in elite jump athletes.

Campos et al (2002) studied on muscular adaptations in response to three resistance –training regimens: specificity of repetition maximum training zones. 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 investigate the "strength-endurance continuum". Subjects 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 fiber-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 rep group. In addition, maximal aerobic power and time to exhaustion significantly increased at the end of the study for only the high rep group. All three major fiber types (types I, IIA, and IIB) hypertrophied for the low rep and int rep groups, whereas no significant increases were demonstrated for either the high rep or con groups. However, the percentage of type IIB fibers decreased, with a concomitant increase in IIAB fibers for all three resistance-trained groups. These fiber-type conversions were supported by a significant decrease in MHC II b accompanied by a significant increase in MHC II a. No significant changes in fiber-type composition were found in the control samples. Although all three training regimens resulted in similar fiber-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 rep 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."

Hickson et al. (1988) found that 10 weeks of a three-times-a-week strength training did not change the VO2max of moderately-trained runners and cyclists. But a short-term (4-8 minutes) endurance test was improved by 12% for both running and cycling, while long-term endurance improved from 70 to 85 minutes for cycling.

Marcinik et al. (1991) showed that strength training had positive effects of endurance cycling capacity. Eighteen males performed 12 weeks of strength training three times a week. The strength training consisted of 8-12 repetitions of upper body exercise (bench press, push-ups, lat pull-downs, arm curls) and 15-20 repetitions on lower body exercises (knee extensions, hip flexion's,
parallel squats) with a 30-second rest between exercises. The strength training program had no effect on the subjects VO2max. However, 1 RM for knee extension and hip flexion improved by 30% and 52% respectively. More important, cycle time to exhaustion at 75% of VO2max improved a massive 33% from 26.3 minutes before strength training to 35.1 minutes after training. He concluded that the "Strength training improves cycle endurance performance independently of changes in VO2max... and that this improvement appears to be related to increase in leg strength."

Toji et al. (2004) studied on the effect of training with a combination of different loads (multiple-load training) on the force-velocity and force-power relationships was examined with training programs that included maximal isometric contraction (Fmax) and concentric contraction of the elbow flexor muscles. Twenty-one male college students were placed into 3 equal training groups (G (30 + 60), G (30 + 100), and G (30 + 60 + 100)) and performed multiple-load training 3 days per week for 8 weeks. The training load was a set fraction of the maximal isometric strength (% Fmax). The G (30 + 60) group performed 6 repetitions of elbow flexion at 30 and 60% Fmax. The G (30 + 100) group performed 6 repetitions at 30% Fmax and six 5-second Fmax loads. The G (30 + 60 + 100) group performed 4 repetitions at 30 and 60% Fmax and four 5-second Fmax loads. After training, Fmax and maximal velocity significantly increased (p < 0.05) in all 3 training groups. The increases in maximal power were significantly (p < 0.05) different between the G (30 + 60 + 100) group (52.9%) and the G (30 + 100) group (24.2%). These results suggest that multiple-load training programs with 4-6 repetitions are effective for improving muscle power and velocity of the elbow flexors.

Toumi et al (2004) studied the effects of jump training as a complement to weight training on jump performance and muscle strategy during the squat and countermovement jump. Twenty-two male handball players, between the ages of 17 and 24, and in good health, were randomly divided into three groups. Two were trained groups, weight training (WTG) and jump training combined with weight training (CTG), and one was a control group (CG). Maximal
isometric force and maximal concentric power were assessed by a supine leg press, squat jump (SJ), counter movement jump (CMJ), and surface EMG was used to determine changes in muscle adaptation before and after the training period. After 6-wk training programs, the two training groups increased maximal isometric force, maximal concentric power, and squat jump performance. However, only combined training presented a significant increase in height jump performance during the countermovement jump (P < 0.05). EMG analysis (as interpreted through the root mean square values) showed that the SJ was performed similarly before and after the training period for the two training groups. However, during the CMJ, only the CTG group adopted a new technique manifested by a short transition phase together with an increase in knee joint stiffness and knee extensor muscle activation and rectus femoris ratio. It was suggested that the central activities in knee joint during the transition phase, in conjunction with intrinsic muscle contractile properties, play a major role in the regulation of performance during a CMJ. Furthermore, our study suggests that a change in maximal strength and/or explosive strength does not necessarily cause changes in combined movement such as the stretch shortening cycle.

There have been numerous studies investigating the effects of weight training on power development and plyometric training while limited research has been carried out investigating the combined effects of plyometric and weight training on vertical jump ability. Much of the research to date comes from authors who use subjects who come from jumping oriented sports (volleyball and basketball), and apply the results of their research directly to these sports. However these training techniques can be applied to many sports which require high levels of explosive leg power as a major physiological component for optimal performance.

Hoff et al., (2000) conducted a study on resistance training loads and the literature proposes that light loads (30% 1 RM) and heavy loads (85% 1 RM) are the appropriate loads to improve dynamic athletic performance, usually the vertical jump. In these formulations, body weight is seldom considered. It could
be an important factor. This investigation used male soccer players performing half-squats under different treatments. A control group (N = 10), a body-weight alone group doing simulated training without external loads (N = 11), a group using an external load of 30% of 1 RM squats (N = 10), and a group using an external load of 85% of 1 RM squats (N = 10) When performing the exercises in the treatment groups, emphasis was placed on the maximal mobilization of force in the concentric portion of the half-squat. Training was 4 x 5 repetitions, three times per week for seven weeks. After each squat training, 3 x 5 vertical counter-movement jumps were performed. In both externally loaded groups, 1 RM increased. Vertical jump improved only in the highest training load group but only when the vertical jump was performed with a 50-kg weight. Vertical jump measures did not improve in outweighed or light-loaded jumping protocols. The highest power production occurred when jumping without any external load. Sprinting tests of 10 and 40 m improved only in the highest-load training group. It was concluded that improving vertical jumping height involved more than just the training load in resistance training. The specificity of the training effects of resistance exercises is again demonstrated in this investigation. There is little to no carry-over of training benefits to actual dynamic performance. However, why Sprint times improved and the specifically targeted vertical jump did not is not addressed. One could propose that sprinting is improved by strength training, but since the training employed only the half-squat, which is more related to vertical jumping and less so to sprinting, the effects are puzzling. The Effects of strength training activities on the performance of a dynamic vertical jump are minimal at best.

Robertson et al (2001) studied on the effects of in-season strength and power training on squat jump performance in NCAA women volleyball players. The effects of four weeks of in-season strength and power training on the ability to rapidly develop force during jumping were evaluated in 12 division I female volleyball players. Testing occurred before and after a traditional strength and power training experience. The dependent variable was force created by the concentric portion of a squat jump. Normal training and competitions occurred during the training period. Time to peak force decreased, peak force increased,
and average concentric force increased. There was no change in the rate of force development, a component of improved speed. Athletes were stronger as a result of the experience while "speed" of force development did not change. Since no control group was used in this study, one is set to ponder whether the strength gains were "retraining gains", because the study implies that no strength training had occurred in-season. If pre-season strength training was experienced and then stopped, resulting in strength-detraining, it is possible the observed changes in this investigation were re-adaptations and possibly unrelated to performance. If strength gains from pre-season training were appropriate for volleyball, their use in training and competitions should have stimulated them to be maintained and additional strength training would have resulted in little to no further gains. Additional in-season strength training improves existing strength in females if they are not undergoing concurrent strength training. The question as to whether the strength gains transfer to improved performance was not answered.

Rutherford et al (1986) studied on the strength training and power output of transference effects in the human quadriceps muscle. "The effect of the training programmes was to produce a large increase in the ability to perform leg extension exercises (160-200%). As the majority of subjects did not take part in regular physical exercise prior to the study, the initial load lifted in training was low. The increase in this load after 12 weeks of training was not accounted for by an increase in isometric strength of the quadriceps (3-20%) and it has been argued that this is most likely due to improved coordination of recruitment of fixated muscles which stabilize the body and allow maximum force to be exerted. If the improvement in performance is due to the establishment of neural pathways it is questionable whether these pathways will be of any use in tasks requiring different patterns of muscular coordination [they will not]. Our measurements of power output substantiate this view. The very considerable improvement in ability to perform leg extension exercises was not reflected in an improvement in power output measured on the cycle ergo meter. The Ss in this investigation were non-athletes so some transfer might have been expected, certainly more than that which would have been hypothesized.
for highly-trained athletes. An increase in strength in a particular quadriceps 
exercise did not affect power output in cycling, an activity that used those same 
muscles both before and after they were strengthened. Neural reorganization is 
specific and such movement patterns do not transfer to other activities even 
those which use the same muscles (but in a different manner).

Kraemer et al. (1994) conducted a study on the factors of training for 
development of vertical jump. The explosive strength is a characteristic of 
performance that is common in many sporting endeavors. However, training 
very frequently includes reduced velocity "strength" training which develops 
capacities which are only appropriate for a very few activities (e.g., power 
lifting). Weight or strength training is often required because it is believed to 
 improve explosive strength. Research has shown that it does increase 
explosive power in individuals who begin training with average strength. 
However, it has little benefit for explosive strength performances for individuals 
with previously trained or above average levels of strength.

Training with heavy loads (70-120% of 1 RM) improves maximal 
isometric strength but not the maximal rate of force development. In some 
cases it might even reduce the ability of the muscles to develop force rapidly. 
On the other hand, light load training with an accent on speed of movement 
increases an athlete's ability to rapidly develop force. A typical total-body 
explosive movement (e.g., vertical jump) requires force to be developed in a 
time period between 200 and 350 ms. Most of the heavy-strength training- 
induced increases in force-producing potential cannot be realized over such a 
short time. Heavy strength training is of little benefit to already strong individuals 
who wish to perform explosive Movements.

Tanaka et al (1998) studied on Impact of resistance training on 
endurance performance. In accordance with the principles of training specificity; 
resistance and endurance training induce distinct muscular adaptations. 
Endurance training, decreases the activity of the glycolytic enzymes, but 
increases intramuscular substrate stores, oxidative enzyme activities, and
capillary, as well as mitochondrial, density. In contrast, resistance or strength training reduces mitochondrial density, while marginally impacting capillary density, metabolic enzyme activities and intramuscular substrate stores (except muscle glycogen). The training modalities do induce one common muscular adaptation: they transform type IIb myofibres into Ila myofibres. This transformation is coupled with opposite changes in fibre size (resistance training increases, and endurance training decreases, fibre size), and, in general, myofibre contractile properties. As a result of these distinct muscular adaptations, endurance training facilitates aerobic processes, whereas resistance training increases muscular strength and anaerobic power. Exercise performance data do not fit this paradigm, however, as they indicate that resistance training or the addition of resistance training to an ongoing endurance exercise regimen, including running or cycling, increases both short and long term endurance capacity in sedentary and trained individuals. Resistance training also appears to improve lactate threshold in untrained individuals during cycling. These improvements may be linked to the capacity of resistance training to alter myofibre size and contractile properties, adaptations that may increase muscular force production. In contrast to running and cycling, traditional dry land resistance training or combined swim and resistance training does not appear to enhance swimming performance in untrained individuals or competitive swimmers, despite substantially increasing upper body strength. Combined swim and swim-specific 'in-water' resistance training programmes, however, increase a competitive swimmer's velocity over distances up to 200 m. Traditional resistance training may be a valuable adjunct to the exercise programmes followed by endurance runners or cyclists, but not swimmers; these latter athletes need more specific forms of resistance training to realise performance improvement.

2.3. STUDIES ON PLYOMETRIC TRAINING

The studies related to effect of plyometric training on criterion measures used in the present study were as follows.
Toplica et al. (2004) have proved experimentally that an eight-week training model using the plyometric method can have an effect on the statistically relevant increase in the explosive type strength of the leg muscles, which in turn leads to an increase in the vertical jump of a block, spike and the long jump.

Luebbers et al. (2003) conducted a study on the effects of plyometric training and recovery on vertical jump performance and anaerobic power. They examined the effects of two 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 pre training (pre), immediately post training (post), and 4 weeks post training (POST-4). Vertical jump height decreased in the 4-week group pre (67.8 +/- 7.9 cm) to post (65.4 +/- 7.8 cm). Vertical jump height increased from pre to post 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.
Other studies demonstrate an enhancement of motor performance associated with plyometric training combined with weight training or the superiority of plyometrics, compared to other methods of training (Adams et al., 1992; Clutch et al., 1983; Delecluse et al., 1995; Duke and BenEliyahu, 1992; Fatourous et al., 2000; Ford et al., 1983; Lyttle et al., 1996; McLaughlin, 2001; Polhemus and Burkherdt, 1980; Potteiger et al. 1999; and Vossen et al., 2000).

M. Brown et al (1996) conducted a study on plyometric training can increase vertical jump performance. It is obvious that, all other things being equal, a player with a good vertical jump will have an advantage over a player with less jumping ability. There is more than one school of thought on the best way to develop this skill.

Brown et al (1986) has shown that plyometric training can improve the vertical jump of high school male basketball players. The vertical jumping ability of 26 freshman and sophomore high school male players (average age = 15 years) was tested after 3 weeks (18 sessions) of practice. Two jump types were measured: a vertical jump in which the arms were free to be used in a double-arm swing (VJA) and one in which the arms were clasped behind the back (VJNA). The group was divided into 2 sub-groups: the "plyometric" group performed 3 sets of 10 repetitions (with 1 minute rest between sets) of depth jumping from a 45 cm bench. A total of 34 training sessions were undertaken over a 12-week period. The "control" group performed normal basketball training only. From the results, it was observed that there was no difference between the 2 groups at the pre-training stage. After training, there was again no difference between the groups for the 'no arms' condition, and both groups had improved their vertical jumping ability. Both groups made significant improvements in their vertical jump when using the arms (21.3% and 17.7% for the plyometric and control groups respectively), but the improvement made by the plyometric group was significantly greater than that made by the control group. The findings support the use of plyometric-style training, in which the muscles are shortened immediately after being loaded eccentrically (i.e. lengthened). The results of this study suggest that 57% of the increase in jump
ability is due to improvements in technique, while the remaining 43% is due to the plyometric training. Thus, while basketball practice alone is sufficient to improve vertical jump performance in high school boys, greater improvements may be generated by employing plyometric training techniques.

Dolezal et al (1998) conducted a study on concurrent resistance and endurance training influence basal metabolic rate in no dieting individuals. Thirty physically active healthy men (20.1 +/- 1.6 yr) were randomly assigned to participate for 10 wk in one of the following training groups: endurance trained (ET; 3 days/wk jogging and/or running), resistance trained (RT; 3 days/wk resistance training), or combined endurance and resistance trained (CT). Before and after training, basal metabolic rate (BMR), percent body fat (BF), maximal aerobic power, and one-repetition maximum for bench press and parallel squat were determined for each subject. Urinary urea nitrogen was determined pre-, mid-, and post training. BMR increased significantly from pre- to post training for RT (7,613 +/- 968 to 8,090 +/- 951 kJ/day) and CT (7,455 +/- 964 to 7,802 +/- 981 kJ/day) but not for ET (7,231 +/- 554 to 7,029 +/- 666 kJ/day). BF for CT (12.2 +/- 3.5 to 8.7 +/- 1.7%) was significantly reduced compared with RT (15.4 +/- 2.7 to 14.0 +/- 2.7%) and ET (11.8 +/- 2.9 to 9.5 +/- 1.7%). Maximal aerobic power increased significantly for ET (13%) but not RT (-0.2%) or CT (7%), whereas the improvements in one-repetition maximum bench press and parallel squat were greater in RT (24 and 23%, respectively) compared with CT (19 and 12%, respectively). Urinary urea nitrogen loss was greater in ET (14.6 +/- 0.9 g/24 h) than in RT (11.7 +/- 1.0 g/24 h) and CT (11.5 +/- 1.0 g/24 h) at the end of 10 wk of training. These data indicate that, although RT alone will increase BMR and muscular strength, and ET alone will increase aerobic power and decrease BF, CT will provide all of these benefits but to a lesser magnitude than RT and ET after 10 wk of training.

Kubachka et al (1966) studied the effects of plyometric training and strength training on the muscular capacities of the trunk. 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.

Hewett et al (1996) conducted a study on the effects of plyometric jump training in females, decreased impact forces and increased hamstrings torques in female athletes with plyometric training. The effect of a jump-training program on landing mechanics and lower extremity strength was assessed in females involved in jumping sports. Responses to a six-week training program were compared to untrained males. The program was designed to decrease landing forces by teaching neuromuscular control of the lower limb during landing and to increase vertical jump height. Training produced a 9.2% increase in vertical jump. Landing training decreased impact forces by reducing medial and lateral torque at the knee, increased power, and decreased hamstrings strength imbalances. Performance can be increased and injury potential decreased if plyometric training is performed along with landing technique instruction with females.

Matavulj et al (2001) conducted a study on the effects of plyometric training on jumping performance in junior basketball players. This study attempted to assess the effects of plyometric training when it is added to the training of adolescent males (N = 33; 15-16 years) who already can jump very well. Three groups of elite junior basketball players were established: a) a control group that only performed regular basketball training, b) a group that performed plyometrics (drop-jumps) from 50 cm, and c) a group that performed
plyometrics from 100 cm. The added training was performed three times per week for six weeks. Both experimental groups improved significantly in the maximal vertical jump (4.8 cm for the 50-cm group and 5.6 cm for the 100-cm group) and rate of force development in the knee extensors. There were no significant differences between the experimental groups in any measure. Drop-jump plyometric training could improve jumping height in adolescent basketball players. [Eventually published as Diallo, O., Dore, E., Duchê, P., & Van Praagh, E. (2001). Effects of plyometric training followed by a reduced training programme on physical performance in prepubescent soccer players.

Hakkinen et al. (2003) conducted a study to investigate effects of concurrent strength and endurance training (SE) (2 plus 2 days a week) versus strength training only (S) (2 days a week) in men [SE: n=11; 38 (5) years, S: n=16; 37 (5) years] over a training period of 21 weeks. The resistance training program addressed both maximal and explosive strength components. EMG, maximal isometric force, 1 RM strength, and rate of force development (RFD) of the leg extensors, muscle cross-sectional area (CSA) of the quadriceps femoris (QF) throughout the lengths of 4/15-12/15 (L(f)) of the femur, muscle fibre proportion and areas of types I, IIA, and IIB of the vastus lateralis (VL), and maximal oxygen uptake (VO2max) were evaluated. No changes occurred in strength during the 1-week control period, while after the 21-week training period increases of 21% (p<0.001) and 22% (p<0.001), and of 22% (p<0.001) and 21% (p<0.001) took place in the 1RM load and maximal isometric force in S and SE, respectively. Increases of 26% (p<0.05) and 29% (p<0.001) occurred in the maximum iEMG of the VL in S and SE, respectively. The CSA of the QF increased throughout the length of the QF (from 4/15 to 12/15 L(f)) both in S (p<0.05-0.001) and SE (p<0.01-0.001). The mean fibre areas of types I, IIA and IIB increased after the training both in S (p<0.05 and 0.01) and SE (p<0.05 and p<0.01). S showed an increase in RFD (p<0.01), while no change occurred in SE. The average iEMG of the VL during the first 500 ms of the rapid isometric action increased (p<0.05-0.001) only in S. VO2max increased by 18.5% (p<0.001) in SE. The present data do not support the concept of the universal nature of the interference effect in strength development and muscle
hypertrophy when strength training is performed concurrently with endurance training, and the training volume is diluted by a longer period of time with a low frequency of training. However, the present results suggest that even the low-frequency concurrent strength and endurance training leads to interference in explosive strength development mediated in part by the limitations of rapid voluntary neural activation of the trained muscles.

Maffiuletti et al (2002) examined the effect of combined electrostimulation and plyometric training on vertical jump height. The study investigated the influence of a 4-wk combined electromyostimulation (EMS) and plyometric training program on the vertical jump performance of 10 volleyball players: Training sessions were carried out three times weekly. Each session consisted of three main parts: EMS of the knee extensor muscles (48 contractions), EMS of the plantar flexor muscles (30 contractions), and 50 plyometric jumps. Subjects were tested before (week 0), during (week 2), and after the training program (week 4), as well as once more after 2 wk of normal volleyball training (week 6). Different vertical jumps were carried out, as well as maximal voluntary contraction (MVC) of the knee extensor and plantar flexor muscles. At week 2, MVC significantly increased (+20% knee extensors, +13% plantar flexors) as compared to baseline ( < 0.05). After the 4-wk training program, different vertical jumps considered were also significantly higher compared to pretraining ( < 0.001), and relative gains were comprised between 8-10% (spike-counter movement jump) and 21% (squat jump). The significant increases in maximal strength and explosive strength produced by the present training program were subsequently maintained after an additional 2 wk of volleyball training. EMS combined with plyometric training has proven useful for the improvement of vertical jump ability in volleyball players. This combined training modality produced rapid increases (approximately 2 wk) of the knee extensors and plantar flexors maximal strength. These adaptations were then followed by an improvement in general and specific jumping ability, likely to affect performance on the court. In conclusion, when EMS resistance training is proposed for vertical jump development, specific work out (e.g., plyometric) must complement EMS sessions to obtain beneficial effects.
Diallo et al (2000) studied on the 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 was divided in two groups (10 in each): jump group (JG) and control group (CG). JG trained 3 days/week during 10 weeks, and performed various plyometric exercises including jumping, hurdling and skipping. The subsequent reduced training period lasted 8 weeks. However, all subjects continued their soccer training. Maximal cycling power (Pmax) was calculated using a force-velocity cycling test. Jumping power was assessed by using the following tests: countermovement jump (CMJ), squat jump (SJ), drop jump (DJ), multiple 5 bounds (MB5) and repeated rebound jump for 15 seconds (RRJ15). Running velocities included: 20, 30 and 40 m (V20, V30, V40 m). Body fat percentage (BF percent) and lean leg volume were estimated by anthropometry. As results, before training, except for BF percent, all baseline anthropometric characteristics were similar between JG and CG. After the training programme, Pmax (p<0.01), CMJ (p<0.01), SJ (p<0.05), MB5 (p<0.01), RRJ15 (p<0.01) and V20 m (p<0.05), performances increased in the JG. During this period no significant performance increase was obtained in the CG. After the 8-week of reduced training, except Pmax (p<0.05) for CG, any increase was observed in both groups. These results demonstrate that short-term plyometric training programmes increase athletic performances in prepubescent boys. These improvements were maintained after a period of reduced training.

Martel et al (2005) studied on aquatic plyometric training increases vertical jump in female volleyball players numerous studies have reported that land-based plyometrics can improve muscular strength, joint stability, and vertical jump (VJ) in athletes; however, due to the intense nature of plyometric training, the potential for acute muscle soreness or even musculoskeletal injury exists. Performance of aquatic plyometric training (APT) could lead to similar benefits, but with reduced risks due to the buoyancy of water. Unfortunately,
there is little information regarding the efficacy of APT. Nineteen female volleyball players (aged 15 +/- 1 yr) were randomly assigned to perform 6 wk of APT or flexibility exercises (con) twice weekly, both in addition to traditional preseason volleyball training. Testing of leg strength was performed at baseline and after 6 wk, and VJ was measured at baseline and after 2, 4, and 6 wk. Similar increases in VJ were observed in both groups after 4 wk (APT = 3.1%, con = 4.9%; both P < 0.05); however, the APT group improved by an additional 8% (P < 0.05) from week 4 to week 6, whereas there was no further improvement in the con group (-0.9%; P = NS). After 6 wk, both groups displayed significant improvements in concentric peak torque during knee extension and flexion at 60 and 180 degrees x s(-1) (all P < 0.05). The combination of APT and volleyball training resulted in larger improvements in VJ than in the con group. Thus, given the likely reduction in muscle soreness with APT versus land-based plyometrics, APT appears to be a promising training option.

Hertogh et al (2002) studied on Jump evaluation of elite volleyball players using two methods: jump power equations and force platform. To determine the best jump power equation in the evaluation of elite volleyball players using both the force platform and peak power equations.: Nine elite volleyball players and nine sedentary subjects performed counter-movement jump tests on a force platform.: Peak power and height were greater in the volleyball players than in the sedentary subjects, whatever the method used. The results demonstrated that the peak power values obtained on the force platform and those scored from the equations of Lewis, Harman and Sayers et al. were correlated when the whole sample was taken into account. However, a significant equation x level interaction (p<10(-4)) indicated different behavior as a function of performance level. In sedentary subjects, peak power was significantly underestimated using the Lewis equation (943 +/- 162 W; p<10(-4)) and did not differ using both the Harman (3004 +/- 563 W) and Sayers (3400 +/- 604 W) equations when compared to the peak power noted with the force platform (3372 +/- 532 W). In contrast, in volleyball players, peak power was underestimated using the three equations (1246 +/- 78 W, p<10(-4); 4314 +/- 216...
W, p<0.001; 4607±251, p<0.005; for the Lewis, Harman and Sayers equations, respectively, versus 5355±522 W for the force platform). The results of the present study demonstrate the difficulty in choosing the most relevant equation in the jump power calculation.

2.4. STUDIES 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. The combination of plyometric training and weight training are thought to be useful for developing athletic power. More specifically, complex training alternates biomechanically similar high load weight training exercises with plyometric exercises, set for set, in the same workout. An example of complex training would include performing a set of squats followed by a set of jump squats. Anecdotal sources have described the application of complex training

Baker et al (2005) studied on the acute effect on power output of alternating an agonist and antagonist muscle exercise during complex training. The efficient coordination of agonist and antagonist muscles is one of the important early adaptations in resistance training responsible for large increases in strength. Weak antagonist muscles may limit speed of movement; consequently, strengthening them leads to an increase in agonist muscle
movement speed. However, the effect of combining agonist and antagonist muscle exercises into a power training session has been largely unexplored. The purpose of this study was to determine if a training complex consisting of contrasting agonist and antagonist muscle exercises would result in an acute increase in power output in the agonist power exercise. Twenty-four college-aged rugby league players who were experienced in combined strength and power training served as subjects for this study. They were equally assigned to an experimental (Antag) or control (Con) group and were no different in age, height, body mass, strength, or maximal power. Power output was assessed during bench press throws with a 40-kg resistance (BT P40) with the Plyometric Power System training device. After warming up, the Con group performed the BT P40 tests 3 minutes apart to determine if any acute augmentation to power output could occur without intervention. The Antag group also performed the BT P40 tests; however, an intervention strategy of a set of bench pulls, which is an antagonistic action to the bench throw, was performed between tests to determine if this would acutely affect power output during the second BT P40 test. Although the power output for the Con group remained unaltered between test occasions, the significant 4.7% increase for the Antag group indicates that a strategy of alternating agonist and antagonist muscle exercises may acutely increase power output during complex power training. This result may affect power training and specific warm-up strategies used in ballistic sports activities, with increased emphasis placed upon the antagonist muscle groups.

Ebben and Watts (1998) reviewed the complex training literature and described the effectiveness of combining weight training and plyometrics. These authors offered suggestions for designing complex training programs, and recommended further research to assess the potential effectiveness of complex training. Interestingly, recent research has examined complex training as well as the ergogenic warm-up benefits associated with weight training exercises performed prior to explosive movements such as jumping (Chu, 1998), Ebben et al 1998., Fees, 1997) Fleck et al (1986) Reddin, 1999) Roque (1999).
Burger et al. (2000) Ebben et al. (2000) Evans et al., 2000; Faigenbaum et al., 1999; Jensen et al. 1999; Radcliffe 1999; Zepeda (2000). These researchers have evaluated the effect of high load weight training and weightlifting exercises and their effect on explosive motor performance referring to this phenomenon as the contrast method (Young et al., 1998). The purpose of this article is to review the recent research related to complex training and the contrast method and its potential practical application.

Blakey et al. (1987), Diallo et al. (2001); Gehri et al. (1998) studied and demonstrate the effectiveness of plyometrics compared to non-exercising control groups.

Rahman Rahimi et al. (2005) conducted a study on the effect of plyometric, weight and plyometric-weight training on anaerobic power and muscular strength. The effect of three different training protocols—plyometric training, weight training, and their combination on the vertical jump performance, anaerobic power and muscular strength. Based on their training, 48 male college students were divided into 4 groups. Plyometric training group (n=13), a weight training group (n=11), plyometric plus weight training group (n=14) and a control group (n=10). The vertical jump, 50 yard run and maximal leg strength were measured before and after a six-week training period. The subjects of each training group trained for 2 days per week, whereas control subjects did not participate in any training activity. The data were analysed by a 1-way analysis of variance (repeated measure design). The results showed that all the training treatments elicited significant (p<0.5) improvement in all of the tested variable. However, the combination training group showed signs of improvement in the vertical jump performance, the 50 yard run, and leg strength that was significantly greater than the improvement in the other 2 training groups (plyometric, weight training groups). This study provides support for the use of combination of traditional weight training and plyometric drills to improve the vertical jump ability, explosive performance in general and leg strength.
Studies (Adams et al., 1992; Clutch et al., 1983; Delecluse et al., 1995; Duke and BenEliyahu, 1992; Fatourous et al., 2000; Ford et al., 1983; Lyttle et al., 1996; McLaughlin, 2001; Polhemus and Burkherdt, 1980; Potteiger et al., 1999; and Vossen et al., 2000) demonstrated an enhancement of motor performance associated with plyometric training combined with weight training or the superiority of plyometrics, compared to other methods of training. The evidence indicates that the combination weight training and plyometrics are effective. One way to combine the two forms of training is complex training or the contrast method. Recent studies have evaluated this type of training with mixed results.

Ebben et al (2000) in his an attempt to quantify differences between complex and non-complex plyometric exercises, one acute study compared electromyographic (EMG) and kinetic variables, such as ground reaction forces, associated with the medicine ball power drop performed before and following a set of 3-5 RM bench press. More specifically, subjects performed the power drop exercise lying supine on a bench press bench that was mounted to a force platform. Subjects caught and forcefully threw the ball upward with horizontal flexion/adduction of the shoulders and extension of the elbow in a movement that is similar to the bench press with the exception that the medicine ball is projected into free space. Results from this study revealed no significant difference for mean or maximum ground reaction force and integrated EMG for the muscles evaluated in each power drop condition. In other words, the medicine ball power drop performed in the complex training condition was equally effective, but not superior, in eliciting motor unit activation or force output compared to the same exercise performed before the 3-5RM bench press set in the non-complex condition.

Jensen et al (1999) The use of complex training as a method of combining weight and plyometric exercises during the same training session is growing in popularity, despite limited scientific support for its efficacy. The purpose of this study was to examine the effect of a set of high-load bench press exercises (BP) on a subsequent set of medicine ball power drop
exercises (MBPD) via mean ground reaction force, maximum ground reaction force, and mean electromyography (EMGint). Ten male (19 ± 1.4 years) NCAA Division 1 basketball players with experience in weight and plyometric training performed plyometric exercises under 2 randomly determined conditions. One condition included a BP followed immediately by a MBPD. The other condition included only the MBPD. Mean ground reaction force, maximum ground reaction force, and EMGint were recorded during the MBPD for both conditions. Results indicated that no significant differences exist for mean ground reaction force, maximum ground reaction force, and EMGint for the pectoralis major and triceps muscles between the MBPD and the BP plus MBPD conditions. These results indicate there is no heightened excitability of the central nervous system. However, there also appears to be no disadvantage of performing high-load weight training and plyometric exercises in complex pairs. Therefore, complex training may be a useful training strategy because of the organizational advantages of performing weight and plyometric exercises in the same training session.

Evans et al (2000) examined the complex training effect of combined bench press and medicine ball throws demonstrating improve plyometric performance in the complex condition. More specifically, one study sought to determine whether or not upper body power could be enhanced by performing a heavy bench press set prior to an explosive medicine ball put. Subjects included 10 college age males with experience performing the bench press. Subjects performed a seated medicine ball put before and four minutes after performing the bench press with a 5RM load. Results indicate a significant increase medicine ball put distance of 31.4 cm (no standard deviation available) following the 5RM bench press compared to the medicine ball put before the bench press. Researchers also report a strong correlation between improvement in medicine ball put distance and 5RM bench press strength.

Complex training research includes acute studies as well as training studies. For example, in an attempt to quantify differences between complex and non-complex plyometric exercises, one acute study compared
electromyographic (EMG) and kinetic variables, such as ground reaction forces, associated with the medicine ball power drop performed before and following a set of 3-5 RM bench press. More specifically, subjects performed the power drop exercise lying supine on a bench press bench that was mounted to a force platform. Subjects caught and forcefully threw the ball upward with horizontal flexion/adduction of the shoulders and extension of the elbow in a movement that is similar to the bench press with the exception that the medicine ball is projected into free space. Results from this study revealed no significant difference for mean or maximum ground reaction force and integrated EMG for the muscles evaluated in each power drop condition. In other words, the medicine ball power drop performed in the complex training condition was equally effective, but not superior, in eliciting motor unit activation or force output compared to the same exercise performed before the 3-5RM bench press set in the non-complex condition (Ebbon et al., 2000). A similar study, using female subjects resulted in the same findings of no significant differences between the complex and non-complex training groups (Jensen et al., 1999).

Other research has examined the complex training effect of combined bench press and medicine ball throws demonstrating improve plyometric performance in the complex condition. More specifically, one study sought to determine whether or not upper body power could be enhanced by performing a heavy bench press set prior to an explosive medicine ball put. Subjects included 10 college age males with experience performing the bench press. Subjects performed a seated medicine ball put before and four minutes after performing the bench press with a 5RM load. Results indicate a significant increase medicine ball put distance of 31.4 cm (no standard deviation available) following the 5RM bench press compared to the medicine ball put before the bench press. Researchers also report a strong correlation between improvement in medicine ball put distance and 5RM bench press strength (Evans et al., 2000).

Research has also examined the effect of complex training while combining total body or lower body strength/power exercises and some form of jumping. Radcliffe et al (1999) examined the "warm-up" effect of the power snatch, backsquat, loaded jumps and tuck jumps on the performance of the
horizontal countermovement jump. Results reveal that when all subjects were combined, no significant warm-up effect existed. When male subjects were analyzed separately, however, the jump distance was greater when performed after the snatch as a weightlifting warm-up. This study used a three-minute rest protocol between sets. This data demonstrates that for males, specific weightlifting exercises may have an ergogenic effect on a subsequent set of jumps.

Young et al (1998) in his study demonstrated a potential acute complex training effect. He evaluated the counter movement jumps (LCMJ) could be enhanced if proceeded by a set of five repetition maximum (5 RM) half squats. Subjects performed two sets of five LCMJ, one set of 5 RM half squats, and one set of five LCMJ with four minutes rest between all sets. The jump height for the LCMJ after the squat was 40.0 cm ± 3.5cm compared to a pre-squat jump height of 39.0 ± 3.3 cm, resulting in a 2.8% improvement in jump performance. The authors indicate that there was a significant correlation between the 5 RM load and jump performances. Results suggest that for complex training, a high load weight training exercise performed four minutes before a power exercise increased the performance of the power exercise, especially for stronger individuals.

Faigenbaum et al., (1999) conducted a study to examine the effectiveness of complex training. For example, one study compared the effects of strength training and complex training in boys and girls (8.1 ± 1.6 years). Results demonstrate that children attain similar gains in upper-body strength and endurance using either strength or complex training programs.

Gonzalez et al (2000), studied using children as subjects, other training studies examined the effects of a three-week complex training program with seven divisions I college female basketball players. Pre and post test results reveal improvement in the 300 m shuttle, 1 mile run, VO2 max, 20 yd dash, pro agility run and the t-test, reverse leg press and back squat. The data show that the complex training program was effective in eliciting statistically significant
improvement in the 300-meter shuttle. However, the research design does not appear to have evaluated the effectiveness of non-complex training combinations of plyometrics and weight training or used a control group.

Zepeda et al. (2000) examined the effectiveness of a complex training group compared to a group who performed all of the weight training exercises after the plyometric exercises. Each group performed the same 7 week routine except the complex training group performed the plyometric exercises in a superset with biomechanically similar resistance training exercises, whereas the other group performed the plyometric exercises separately, following the resistance training exercises. Subjects included seventy-eight division I college football players. Subjects were pre and post-tested with a variety of tests including percentage of body fat, bench press, squat, power clean, medicine ball throw, broad jump, and vertical jump. Both groups demonstrated improvement in all eight of the tests. However, the complex training group demonstrated significant between group vertical jumps improvements (2.8 cm) compared to the non-complex training group (0.1 cm).

Ebben and Watts (1998) reviewed the research on various combinations of weight training and plyometric training as well as complex training. At that time, despite numerous brief references to complex training in the literature, only one training study specifically examined complex training. The results from that study were difficult to interpret, however, due to the absence of published numerical data (Verkhoshansky and Tetyan, 1973). According to Ebben and Watts (1998), complex training program design must consider important variables such as exercise selection, load, and rest between sets. Recent research offers additional guidelines regarding these variables and raises the question about age and gender specific effects as well.

Radcliffe et al (1999) in theirs study suggested that the recent acute complex training may be effective for upper body, and lower body training it may be more effective for males. Additionally, prerequisite strength and the intensity of the load (RM) used in the weight training portion of the complex may
be important in eliciting a complex training effect during the plyometric condition (Young et al. 1998).

Evans et al (2000), Radcliffe et al (1999), Young et al (1998) in their recent research also suggests that three to four minutes of rest between the weight training and plyometric training portions of the complex may be optimal. Ultimately, even the study that demonstrated no advantage associated with performing power drops after the bench press showed that performing plyometrics in complex training is at least as effective as performing them in a non-complex fashion.

Zepeda and Gonzalez (2000) recently studies on complex training and examined the effect of complex training for children and female athletes suggests that complex training was equally as effective, but not superior to other strength training programs. This finding may be consistent with the idea that prerequisite strength is necessary for complex training to be most effective and that this type of training may be best suited for those who are highly trained (Faigenbaum et al 1999).

Burger et al (2000) concluded in his study which is contrast to the effectiveness of complex training was demonstrated in part, with male division I college football players. In this case, researchers found that the complex training group demonstrated significant between group vertical jump improvements. The vertical jump performance improvement associated with complex training is consistent with the purported role of complex training as an effective training strategy for improving power. Evidence suggests that jumping ability seems to demonstrate an acute improvement in response to complex training stimulus according to the findings of Young et al. (1998) as well as improving as a result of a chronic complex training stimulus.

Jensen et al (2003) studied on the kinetic analysis of complex training, rest interval on vertical jump performance. Complex training has been recommended as a method of incorporating plyometrics with strength training.
Some research suggests that plyometric performance is enhanced when performed 3-4 minutes after the strength training set, whereas other studies have failed to find any complex training advantage when plyometrics are performed immediately after the strength training portion of the complex. The purpose of this study was to determine if there is an ergogenic advantage associated with complex training and if there is an optimal time for performing plyometrics after the strength training set. Subjects were 21 NCAA Division I athletes who performed a countermovement vertical jump, a set of 5 repetitions maximum (5 RM) squats, and 5 trials of countermovement vertical jump at intervals of 10 seconds and 1, 2, 3, and 4 minutes after the squat. Jump height and peak ground reaction forces were acquired via a force platform. The pre-squat jump performance was compared with the post-squat jumps. Repeated measures ANOVA determined a difference (p </= 0.05) between genders and that jump performance immediately following the squat exercise was hindered (0.66 m), but no effect (p > 0.05) was found comparing subsequent jumps (0.72-0.76 m) to the pre-squat condition (0.74 m). When comparing high to low strength individuals, there was no effect on jump performance following the squat (p > 0.05). In conclusion, complex training does not appear to enhance jumping performance significantly and actually decreases it when the jump is performed immediately following the strength training set; however, a non significant trend toward improvement seemed to be present. Therefore to optimize jump performance it appears that athletes should not perform jumps immediately following resistance training. It may be possible that beyond 4 minutes of recovery performance could be enhanced; however, that was not within the scope of the current study.

2.5. STUDIES ON SKILL PERFORMANCE

Gabbett et al (2006) investigated the effect of a skill-based training program on measurements of skill and physical fitness in talent-identified volleyball players. Twenty-six talented junior volleyball players (mean +/- SE age, 15.5 +/- 0.2 years) participated in an 8-week skill-based training program that included 3 skill-based court sessions per week. Skills sessions were
designed to develop passing, setting, serving, spiking, and blocking technique and accuracy as well as game tactics and positioning skills. Coaches used a combination of technical and instructional coaching, coupled with skill-based games to facilitate learning. Subjects performed measurements of skill (passing, setting, serving, and spiking technique and accuracy), standard anthropometry (height, standing-reach height, body mass, and sum of 7 skinfolds), lower-body muscular power (vertical jump, spike jump), upper-body muscular power (overhead medicine-ball throw), speed (5- and 10-m sprint), agility (T-test), and maximal aerobic power (multistage fitness test) before and after training. Training induced significant (p < 0.05) improvements in spiking, setting, and passing accuracy and spiking and passing technique. Compared with pretraining, there were significant (p < 0.05) improvements in 5- and 10-m speed and agility. There were no significant differences between pretraining and posttraining for body mass, skinfold thickness, lower-body muscular power, upper-body muscular power, and maximal aerobic power. These findings demonstrate that skill-based volleyball training improves spiking, setting, and passing accuracy and spiking and passing technique, but has little effect on the physiological and anthropometric characteristics of players.

Bénédicte Forthomme et al (2005) studied on the factors correlated with volleyball spike velocity. Spike effectiveness represents a determining element in volleyball. To compete at a high level, the player must, in particular, produce a spike characterized by a high ball velocity. Some muscular and physical features could influence ball velocity during the volleyball spike. A total of 19 male volleyball players from the 2 highest Belgian national divisions underwent an isokinetic assessment of the dominant shoulder and elbow. Ball velocity performance (radar gun) during a spike test, morphological feature, and jump capacity (ergo jump) of the player were measured. We tested the relationship between the isokinetic parameters or physical features and field performances represented by spike velocity. He also compared first-division and second-division player data. Spike velocity correlated significantly with strength performance of the dominant shoulder (internal rotators) and of the dominant elbow (flexors and extensors) in the concentric mode. Negative correlations
were established with the concentric external rotator on internal rotator ratio at 400 deg/s and with the mixed ratio (external rotator at 60 deg/s in the eccentric mode on internal rotator at 240 deg/s in the concentric mode). Positive correlations appeared with both the volleyball players' jump capacity and body mass index. First-division players differed from second-division players by higher ball velocity and increased jump capacity. Some specific strength and physical characteristics correlated significantly with spike performance in high-level volleyball practice.

Sawyer et al (2002) examined the relationships between football playing ability (FPA) and selected anthropometric and performance measures were determined among NCAA Division I-A football players (N = 40). Football playing ability (determined by the average of coach's rankings) was significantly correlated with vertical jump (VJ) in all groups (offense, defense, and position groups of wide receiver-defensive back, offensive linemen-defensive linemen, and running back-tight end-linebacker). Eleven of 50 correlations (groups by variables), or 22%, were important for FPA. Five of the 11 relationships were related to VJ. Forward stepwise regression equations for each group explained over half of the criterion variable, FPA, as indicated by the R(2) values for each model. Vertical jump was the prime predictor variable in the equations for all groups. The findings of this study are discussed in relation to the specificity hypothesis. Strength and conditioning programs that facilitate the capacity for football players to develop forceful and rapid concentric action through plantar flexion of the ankle, as well as extension of the knee and hip, may be highly profitable.

Baker (2001) examined the effect of an in-season of concurrent training on the maintenance of maximal strength and power in professional and college-aged rugby league football players. Fourteen professional (NRL) and 15 college-aged (SRL) rugby league players were observed during a lengthy in-season period to monitor the possible interfering effects of concurrent resistance and energy-system conditioning on maximum strength and power levels. All subjects performed concurrent training aimed at increasing strength, power,
speed, and energy-system fitness, as well as skill and team practice sessions, before and during the in-season period. The SRL group significantly improved 1 repetition maximum bench press (1RM BP) strength, but not bench throw (BT Pmax) or jump squat maximum power (JS Pmax) over their 19-week in-season. The results for the NRL group remained unchanged in all tests across their 29-week in-season. The fact that no reductions in any tests for either group occurred may be due to the prioritization, sequencing, and timing of training sessions, as well as the overall periodization of the total training volume. Having athletes better conditioned to perform concurrent training may also aid in reducing the possible interfering effects of concurrent training. Correlations between changes in 1RM BP and BT Pmax suggest differences in the mechanisms to increase power between stronger, more experienced and less strong and experienced athletes.

Hakkinen (1993) conducted a study on the changes in physical fitness profile in female volleyball players during the competitive season. Nine members of a female volleyball team served as experimental subjects in order to examine changes in a physical fitness profile during the competitive season consisting of a first season (I) for 10 weeks followed by season II for 11 weeks. The entire season was characterized by 4-5 weekly sessions for playing drills and competitive games and by 2-3 weekly sessions for physical conditioning mostly for strength and explosive strength training. The control group consisted of eight other female volleyball players who trained for physical conditioning during the competitive season 1-2 times per week. The present findings showed that the entire competitive season in experimental subjects led to no changes (from 47.3 +/- 1.7 to 48.1 +/- 3.4 ml x kg^-1 x min^-1) (n.s.) in VO2max but a significant (p < 0.05) decrease took place in average power in a 30 s anaerobic jumping test. Significant increases took place in the maximal vertical jumping heights in the squat (from 30.3 +/- 1.7 to 31.6 +/- 1.3 cm) (p < 0.05) and in the counter movement jump (from 32.8 +/- 1.6 to 34.3 +/- 1.3 cm) (p < 0.05) as well as in the spike and block jumps (p < 0.05) during competitive season.

Eom et al (1992) studied on the transition play in team performance of volleyball. The purpose of this study was to develop and test a method to
A computerized system was developed to record and summarize the sequential skill performances in volleyball. Seventy-two sample games from the third Federation of International Volleyball Cup men's competition were videotaped and grouped into two categories according to the final team standing and game outcome. Log-linear procedures were used to investigate the nature and degree of the relationship in the first-order (pass-to-set, set-to-spike) and second-order (pass-to-spike) transition plays. Results showed that there was a significant dependency in both the first-order and second-order transition plays, indicating that the outcome of a skill performance is highly influenced by the quality of a preceding skill performance. In addition, the pattern of the transition plays was stable and consistent, regardless of the classification status: Game Outcome, Team Standing, or Transition Process. The methodology and subsequent results provide valuable aids for a thorough understanding of the characteristics of transition plays in volleyball. In addition, the concept of sequential performance analysis may serve as an example for sport scientists in investigating probabilistic patterns of motor performance.

Smith et al (1992) conducted a study on the physical, physiological and performance differences between Canadian national team and universidad volleyball players. This investigation compared teams at the two uppermost levels of men's volleyball in Canada for differences in physical, physiological and performance characteristics. The subjects were members of the national (n = 15) and universiade teams (n = 24). The parameters examined included percent body fat, maximal oxygen uptake (VO2 max), anaerobic power, bench press, 20-m sprint time and vertical jumping ability. The only significant difference in physical characteristics between the two teams was in age. Despite similarities in standing and reach height, the national team players had significantly higher block (3.27 vs 3.21 m) and spike (3.43 vs 3.39 m) jumps. An evaluation of anaerobic power measures produced similar power outputs during a modified Wingate test, yet the national team members had higher scores (P less than 0.05) for spike and block jump differences as well as 20-m sprint time. The large aerobic component of elite volleyball play was supported by the high
VO2 max value recorded for the national team players (56.7 vs 50.3 ml kg⁻¹ min⁻¹). The results suggest that either years of specific physical conditioning and playing or the selection of individuals for the national team who possess more desirable characteristics as a consequence of genetic endowment, plays a significant role in the preparation of international calibre volleyball players.

Sawyer et al (2002) studied on the relationship between football playing ability and performance measures. The relationships between football playing ability (FPA) and selected anthropometric and performance measures were determined among NCAA Division I-A football players (N = 40). Football playing ability (determined by the average of coaches’ rankings) was significantly correlated with vertical jump (VJ) in all groups (offense, defense, and position groups of wide receiver-defensive back, offensive linemen-defensive linemen, and running back-tight end-linebacker). Eleven of 50 correlations (groups by variables), or 22%, were important for FPA. Five of the 11 relationships were related to VJ. Forward stepwise regression equations for each group explained over half of the criterion variable, FPA, as indicated by the R(2) values for each model. Vertical jump was the prime predictor variable in the equations for all groups. Strength and conditioning programs that facilitate the capacity for football players to develop forceful and rapid concentric action through plantar flexion of the ankle, as well as extension of the knee and hip, may be highly profitable.

Tsunawake et al (2003) conducted a study on the body the Body composition and physical fitness of female volleyball and basketball players of the Japan inter-high school championship teams. This study evaluated the body composition (underwater weighing) and cardiorespiratory function (VO2max and O2 debt max measured by the treadmill exercise test) in 12 members of the women's volleyball team (mean age 17.4 years) and 11 members of the women's basketball team (mean age 17.6 years) that won the championship in the Japan Inter-high School Meeting. He also examined the differences in the physical abilities between the members of the top teams of different events. From the results of this study, it was observed that the female
volleyball players and basketball players evaluated in this study had the physical abilities needed to win the championship in the Japan Inter-high School Meets, i.e. a large FFM and excellent aerobic and anaerobic work capacities. Also, basketball appears to require higher aerobic and anaerobic work capacities than volleyball.

Stamm et al (2003) conducted a study on the dependence of young female volleyballers' performance on their body build, physical abilities, and psycho-physiological properties. The study was designed to determine the success of adolescent female volleyball players either anthropometric characteristics, physical abilities or psycho-physiological properties at competitions. For this purpose he studied 32 female volleyballers aged 13-16 years. The anthropometric examination included 43 measurements, 7 tests of physical fitness, and 4 series of computerised psycho-physiological tests (n=21). The performance of game elements was measured empirically during championship games using the original computer program "Game". The proficiency of performing volleyball elements - serve, reception, feint, block and spike - was calculated by regression models from the 14 anthropometric measurements, 4 physical fitness and 7 psychophysiological test results, which showed significant correlation with proficiency in the game. The predictive power of the models was at least 32% and in average 56%. The anthropometric factor was significant in the performance of all the elements of the game, being most essential (71-83%) for attack, block and feint. Good results in physical ability tests granted success in serve, attack and reception. It was possible to predict the efficiency of reception (44%) by endurance, flexibility and speed measuring tests. Medicine ball throwing test was essential for attack (22%). Psycho-physiological tests were significant for the performance of block (98%), attack (80%), feint (60%) and reception (39%).

Gorostiaga et al (2005) studied the differences in physical fitness and throwing velocity among elite and amateur male handball players. This study compared physical characteristics (body height, body mass [BM], body fat [BF], and free fatty mass [FFM]), one repetition maximum bench-press (1RM (BP)),
jumping explosive strength (VJ), handball throwing velocity, power-load relationship of the leg and arm extensor muscles, 5- and 15-m sprint running time, and running endurance in two handball male teams: elite team, one of the world’s leading teams (EM, n = 15) and amateur team, playing in the Spanish National Second Division (AM, n = 15). EM had similar values in body height, BF, VJ, 5- and 15-m sprint running time and running endurance than AM. However, the EM group gave higher values in BM (95.2 +/- 13 kg vs. 82.4 +/- 10 kg, p < 0.05), FFM (81.7 +/- 9 kg vs. 72.4 +/- 7 kg, p < 0.05), 1RM (BP) (107 +/- 12 kg vs. 83 +/- 10 kg, p < 0.001), muscle power during bench-press (18 - 21 %, p < 0.05) and half squat (13 - 17 %), and throwing velocities at standing (23.8 +/- 1.9 m . s (-1) vs. 21.8 +/- 1.6 m . s (-1), p < 0.05) and 3-step running (25.3 +/- 2.2 m . s (-1) vs. 22.9 +/- 1.4 m . s (-1), p < 0.05) actions than the AM group. Significant correlations (r = 0.67 - 0.71, p < 0.05 - 0.01) were observed in EM and AM between individual values of velocity at 30 % of 1RM (BP) and individual values of ball velocity during a standing throw. Significant correlations were observed in EM, but not in AM, between the individual values of velocity during 3-step running throw and the individual values of velocity at 30 % of 1RM (BP) (r = 0.72, p < 0.05), as well as the individual values of power at 100 % of body mass during half-squat actions (r = 0.62, p < 0.05). The present results suggest that more muscular and powerful players are at an advantage in handball. The differences observed in free fatty mass could partly explain the differences observed between groups in absolute maximal strength and muscle power. In EM, higher efficiency in handball throwing velocity may be associated with both upper and lower extremity power output capabilities, whereas in AM this relationship may be different. Endurance capacity does not seem to represent a limitation for elite performance in handball.