CHAPTER – II

REVIEW OF RELATED LITERATURE

An essential aspect of research project is the review of related literature. Survey of the literature is a crucial aspect of the planning of the study and the time spend in such a survey is a wise investment. The study of the relevant literature is an essential step to get a full picture of what has been done and said with regard to the problem understudy. Such a review brings about deep insight and clear perceptive of the overall field\(^1\).

The search for reference materials is time consuming but fruitful phase of the graduate programme. A familiarity with the literature in any problem area helps the student to discover what others have attempted to find out, what methods of attack have been promising and problems remain to be solved\(^2\).

The review of literature helped the investigator to spot out relevant topics and variables. Further the literature helped the investigator to frame the suitable hypothesis leading to the problems. The latest literature also helped the investigator to support the researcher’s feelings with regard to the problem.

In order to support the presentation and analysis of the study, the research scholar has collected reference materials from various books and journals. While numerous studies have been conducted on the training methods for different games and sports, not much work has been done specifically on varied packages of physical trainings. The packages of

physical training consists of various training methods like slow continuous run, extensive interval run, intensive internal run, weight training, speed training, technique training, fartlek training, circuit training, plyometric training, Hill or slope running etcetera.

2.1 STUDIES ON CARDIO RESPIRATORY ENDURANCE

Faria\(^3\) conducted a study on forty college men who were randomly divided into three training groups and one control group in a study of selected cardiovascular adaptation to four week of training boats eliciting either 120-130, 140-150 or 160-170 heart rates. Training consisted of bench stepping until the assigned heart rate was elicited five days per week. Significant changes were found in the analysis of pre-post 180 work capacity (PWC-180). Analysis of group different revealed that the 140-150 and 160-170 training group improvement was significantly different from other groups. No other difference was statistically significant. No changes were noted in recovery heart rate. The study supported the hypothesis that when training to improve one’s physical capacity to do work, the severity of the training effect is related but not proportional to intensity of the training.

Norrell and Mark\(^4\) conducted a study on, the effect of an eleven week super circuit exercise programme on selected physiological measures of University of Albana Police Officers. The efficient exercise programme of police officers could be enhanced by a time requirements. The purpose of the study was to measure the effect of a “super circuit” exercise programme on University of Albana Police Officers. Nineteen male and three female officers participated in the (eleven week) programme preceding and following the

\(^3\) Irrin E. Faria, “Cardio vascular Response to Exercise as Influenced by Training of Various Intensities, Research Quarterly, 41:1 (March 1990), 44

training period number of health and occupational related fitness measure work taken in the participants. The programme consisted of nine resistance exercises stations interspersed with nine aerobic exercise stations. The resistance was provided by Hydra Fitness Omnikinalic Exercise Machines. After a short warm up which consisting of stretching and mild calisthenics, the officers exercised continuously for 27 minutes, alternating 20 seconds at each resistance station with forty second at each aerobic station for three complete circuits. The officers were instructed to try and make three exercise sessions per week with at least one day of recovery between the work outs. Despite some attendance problems, the training programme brought about many favorable changes in fitness. Multi variate analysis revealed significant gains in the cardiovascular fitness as evidenced by a 15% increase in tread mill test performance. Benefits to cardiovascular fitness were also realized in a reduction of resting and exercise recovery heart rate (7% and 13% respectively). There were also significant increase in lower legs strength (7%), upper legs strength (15%), vertical jump (12.5%) and sit up (37%). Increase, in the bench press strongly approached significance. There were no significant changes in push ups, sit and reach, grip strength, state anxiety, blood pressure. There were no favorable changes in body composition. It was concluded that “super circuit” exercise programme does appears to be a time efficient programme for eliciting and maintaining physical fitness among University of Alabna Police officers. The programme was sufficient to bring about changes in the majority of fitness variables tested, cardiovascular endurance, muscular strength, endurance, and power.

Sanoto and Del\textsuperscript{5} conducted a study to find out the effects of physical conditioning programme on selected physiological components of college age men. The subjects were seventy six men from a junior college. They were

\textsuperscript{5} Sanoto and Frank Del, “A Study of the Effects of Physical Conditioning Programme on Selected Physiological Components of College age Men, “\textit{Dissertation Abstracts International}, 36:12 (June 1976), 79.
divided into four groups. Three of whom were participated different conditioning programme and one was control group which had no formed physical conditioning programme. In the results, the interval conditioning, aerobic conditioning and regular physical education groups improved significantly in cardiovascular fitness in comparison to the control group. The interval conditioning group showed that testing blood pressure was significantly lower in comparison to the control group. The interval conditioning showed significantly more recovery heart rates following maximal work on the regular physical education group. The control group did not improve in its cardiovascular fitness.

**Gregory**\(^6\) conducted research on untrained college males who were randomly assigned to one of the two Experimental groups and control group. He took four, seven and seven subjects in the control, interval running and continuous running groups respectively. Training consisted of jogging or running on a quarter mile track for a distance of two miles, five days a week and for the period of six weeks. The intensity of run was controlled by keeping the pulse count at 162 beats and 174 beats per minute, for continuous and interval running group respectively. It was concluded that continuous and interval running methods were equally effective in developing aerobic capacity when the same total work is performed.

**Gentry and Roy**\(^7\) studied the effects of a nine weeks aerobic jogging programme on selected cardiovascular functions of the young male students of college through a time course evaluation process. Fifteen male students of college ranging in the age from eighteen to twenty two years, participated in

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the study, the subjects were administered a predictive maximum oxygen uptake test prior to the training period to ensure that each person was initially placed in the proper fitness category. Once training commenced, each subject progressed at his own rate, depending upon his level of fitness and rate of adaptation. In this instance, the training programme consisted of jogging or walking a specified distance (one or two times) five times per week the results indicated significant decrease in resting diastolic blood pressure and steady state heart rate, while no change occurred in exercise cardiac output, resting and exercise cardiac index and resting heart rate.

Harper, Billings and Mathews\(^8\) conducted a study of the effects of two physical conditioning programme on cardio respiratory fitness of twenty five college men. The subjects were placed into three matched groups on the basis of maximum oxygen consumption. One group participated in the modified army conditioning programme of calisthenics and marching while the second group participated in a programme of interval training involving running. The third group participated in recreational activities. The group met five days per week for seven weeks. Cardio respiratory efficiency was measured by the help of Harvard Step test. The result showed that both intervals trained and army trained groups improved significantly in their cardiovascular efficiency, the control group did not significantly improve.

Kibban\(^9\) conducted a study on the comparison of three work load of varying intensities and distance on cardio respiratory endurance, divided the subjects in to three groups. Group I trained at a heart rate of 150 beats per minute for fifteen minutes, Group II trained at a rate ranging from 120 to 180


\(^{9}\) Stiphen Allan Mc Kibban, “A Comparison of Three Week Loads of Varying Intensity and Distance on Cardio Respiratory Endurance, ”Dissertation Abstracts International, 34:1 (May 1974), 7029-A.
beats per minutes for fifteen minutes. Group III trained at a rate of 150 beats per minute over a distance run by group II. Subjects were trained five days a week. It was concluded that running for fifteen minutes a day at a heart rate of 150 beats per minute for seven weeks significantly increased cardio respiratory endurance.

Uppal and Tunidan\textsuperscript{10} studied the comparative effect of different frequencies of endurance training on cardio respiratory endurance. According to their findings the cardio respiratory endurances of secondary school students could be effectively improved by administering a progressive programme of interval training. To bring about significant improvement in cardio respiratory endurance, varied frequencies of training namely twice, thrice and five days a week was employed. Endurance training work out using interval running method, administered, three and five days a week were more effective in developing Cardio-respiratory endurances as compared to work outs twice a week.

Yeager and Brynnteson\textsuperscript{11} sampled eighteen female volunteers and they were randomly divided into three experimental groups which trained 10, 20 or 30 minutes a day at a heart rate of 144 beats per minute, three days per week for six weeks on a bicycle ergometer. The subjects were tested before and after the conditioning programme on cardiovascular efficiency. The two tests administered during each testing period were the Astrand test of predicted maximal oxygen uptake and a test physical work capacity. The results indicated that all three groups significantly improved in cardiovascular efficiency between Tests I and Test II predicted maximal oxygen values.


increased five, five and eight ml.kg per minute in the 10-20 and 30 minute
groups respectively. Times in physical work capacity test increased 24, 50
and 35 seconds in the three respective groups the 30 minute group however,
showed a more consistent increase in cardiovascular efficiency than the other
two.

2.2. STUDIES ON ANAEROBIC POWER

Manning, Dooly-Manning and Perrin\textsuperscript{12} conducted a study on the
factor analysis of various anaerobic power testes. There are numerous field
and laboratory anaerobic power tests used by physical educators, coaches,
trainers and researchers to predict an individual's anaerobic power. Thirty one
college males were used in this study in order to identify the single best test
as well as correlate various anthropometric and isokinetic measures with
various anaerobic power tests. The anaerobic power tests used where the
vertical jump using the Lewis formula, the Margaria-Kalamen test, the Cybex
11 isokinetic measures for knee extension and angle planter flexion at 180
and 240 deg/sec, the 40 yards dash and the standing long jump. Significant
correlation at the P<0.008 were used in principal factor analysis and then
rotated using the varimax criterion. Results showed no single factor emerged.
Results also showed that unrelated aspects exist among these tasks and that
they are not measuring similar quantities. It is suggested that anaerobic tests
which were used to evaluate anaerobic power be performed as specifically as
the skill being tested.

\textsuperscript{12} James M. Manning, Cathryn Dolly-Manning and David H. Perrin, “Factors
Analysis of Various Anaerobic Power Tests, “\textit{The Journal of Sports Medicine and
Housh\textsuperscript{13} conducted a study on the relationship between anaerobic running capacity and peak plasma lactate. Twelve adult males (\(x \text{ age} \pm \text{SD} = 21.9 \pm 1.2 \text{ years}\)) performed a critical velocity test from which anaerobic running capacity was determined and maximal tread mill running test from which peak plasma lactate was determined from post exercise blood samples taken at one minute intervals. The results indicated that anaerobic running capacity (\(X \pm \text{SD} = 0.18 \pm 0.04 \text{ km}\)) was not significantly (\(r = -0.06, p>0.05\)) correlated with peak plasma lactate (9.3 ± 1.8 mm). These findings do not support anaerobic running capacity as indirect indicator of anaerobic capabilities.

Shaver\textsuperscript{14} conducted a study on maximum aerobic power work capacity prediction from various running performance on untrained college men. A Group of thirty untrained college males aged 18 to 20 years volunteered for test on 100, 200, 400 and 800 yards runs as well as one and three miles runs. No practice session were given for the track running. In addition the subjects were tested for maximum aerobic capacity as measured by method of margarita. It was concluded that distance beyond half mile are significantly related to aerobic work capacity and distance up to and including quarter mile are significantly to anaerobic work capacity.

Colemen\textsuperscript{15} and others studied nine college basketball players to determine the effect of season of competition on aerobic and anaerobic energy source. Pretest and post test were conducted on variable of the


resting and recovery heart rates, performance on treadmill, maximum oxygen intake and the source of Margaria’s anaerobic capacity test. Analysis of data fielded non-significant decrease in recovery heart rate, treadmill performance time and VO₂ max and a non-significant increase in vertical velocity from pre and post tests. The results of these investigations suggest that the training session in basketball was of significant intensity to maintain cardiorespiratory function and improve anaerobic performance.

Taine and Paul\textsuperscript{16} investigated the effect of varied level of intensity and quantity of run training on the aerobic and anaerobic thresholds. Subjects were 40 moderately conditioned (aerobic thresholds between 55% to 70% of maximal oxygen uptake) males. All subjects were pre-tested on a treadmill to determine maximal oxygen uptake, aerobic and anaerobic thresholds. Performance capacity was measured with a 3.22 km run. Subjects were assigned randomly to one of the six experimental groups and of a control group. Subjects trained for ten weeks, five days per week at a low, medium or high intensity. At the end of weeks subjects were post-tested on all dependent variables. Planned comparison revealed that the aerobic threshold treadmill, velocity, oxygen uptake and relative oxygen uptake increase significantly more in the medium and high intensity group than in the low intensity group. None of the aerobic threshold dependent variables increased significantly more in the high than in the medium and low intensity group. The results of the study partially supported the theory that there is an intensity threshold above which training must occur in order to improve the aerobic threshold. The combined groups improved a non-significant 4.7% on the 3.22 km run while maximal oxygen uptake in the combined groups increased non-significantly by 2.4% finally in the moderately conditioned subjects, quantity of

\textsuperscript{16} Lafon Taine and Thomas Paul, "The Effects of Intensity and Quantity of Exercise Training on the Aerobic and Anaerobic Threshold," \textit{Dissertation Abstract International}, 45, (Feb 1984), 452
training was not a significant factor for improvement in the aerobic and anaerobic thresholds.

McArton\textsuperscript{17} carried out an investigation to identify and measure the specific effects of three forms of anaerobic training. All subjects participated in the pre test and an identical post training a forty second maximal rate on bicycle ergometer with a resistance of seven kilo pounds. Expired gas was collected during the test for the period of thirty one minutes of recovery work and intensity reading was recorded for the measurement of aerobic power and total power. A blood sample was drawn during the recovery period. It was concluded that the training programme which concentrate on the development of aerobic power will increase the capacities for the anaerobic energy output although the specific training programme may not differ significantly in their abilities to develop scientific components of anaerobic power.

Katch\textsuperscript{18} et. al conducted to ascertain the optimum protocol for a maximum anaerobic work output test on the bicycle ergometer from 58 subjects indicated that the test duration needs to be approximately 40 sec. and the optional functional resistance 30 to 36 kpm. The results of these two experiments, under taken to ascertain the optimum test characteristics for the maximum anaerobic functioning on the bicycle ergometer, indicate that the test should be approximately 40 sec. duration at a fractional resistance of 5.0 to 6.0 kpm with an all out cycling cadence.


\textsuperscript{18} Victor Katch et. al., “optimal Test Characteristics for Maximal Anaerobic Work on the Bicycle Ergometer,” \textit{Research Quarterly} 48 (May 1977), 319-326
Luebbers\textsuperscript{19} (November 2003) done an experimental research on “Effects of plyometric training and recovery on vertical jump performance and anaerobic power”. The study contains the following. We examined the effects of 2 plyometric training programs, equalized for training volume, followed by a 4 week recovery period of no plyometric training on anaerobic power and vertical jump performance. Physically active, college-aged men were randomly assigned to either a 4-week (n =19, weight = 73.4 +/- 7.5 kg) or a 7-week (n = 19, weight = 80.1 +/- 12.5 kg) program. Vertical jump height, vertical jump power, and anaerobic power via the Margarita 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-4 in 4-week (67.8 +/- 7.9 to 69.7 +/-7.6 cm) and 7 week (64.6 +/- 6.2 to 67.2+/- 7.6 cm) training programs. Vertical jump power decreased in the 4-week group from PRE (8,660.0 +/- 546.5 W) to POST (8,541.6 +/- 557.4 W) with no change in the 7-week group. Vertical jump power increased PRE to POST -4 in 4 week (8,660.0 +/- 546.5 W to 8,793.6 +/- 541.4 W) and 7 week (8,702.8 +/- 527.4 W to 8,931.5 +/- 537.6 W) training programs. Anaerobic power improved in the 7-week group from PRE (1,121.9 +/- 174.7 W) to POST (1,192.2 +/- 189.1 W) but not the 4 week group. Anaerobic power significantly improved PRE to POST-4 in both groups. There were no significant differences between the 2 training groups. Four week and 7-week plyometric programs are equally effective for improving vertical jump height, vertical jump power, and anaerobic power when followed by a 4 week recovery period. However, a 4-week program may not be as effective as a 7 week program if the recovery period is not employed.

2.3. STUDIES ON PULSE RATE

Varijens\textsuperscript{20} in his study compared eleven volunteers with nine students in a scheduled physical education class. The groups were considered to be equivalent in anthropometrical and functional tests. The experimental group (N = 11) participated in circuit training which consists of ten exercise programme in addition to the regular physical education programme for a period of six weeks with three training sessions per week. Favorable effects on both functional and morphological parameters were obtained. Maximum oxygen intake and $O_2$ Pulse were increased. Pulse rate adaptation was more efficient and heart volume was enlarged.

Chloeking\textsuperscript{21} studied the effects of two training on the selected circulo-respiratory variables on college women. The physiological reactions measured were pulse rate, respiration rate, respiration amplitude, minute volume of respiration and oxygen consumption. The respiratory variables were recorded simultaneously by a respirator. The cardiovascular reaction was measured by counting the pulse rate. All variables improved during regardless of the training programme prescribed. Both training programme were of sufficient duration and intensity to affect changes in post exercise scores.


2.4. STUDIES ON MOTOR ABILITY COMPONENTS

**Wilfred Keller**\(^{22}\) conducted a study on supplementary aerobic training on sprinter. The purpose of the study was to determine whether additional aerobic training over and above the primary aerobic training typical of collegiate sprinters, had effect on sprint times and other measures of anaerobic and aerobic performance. He conducted that the aerobic training had some positive effects with respect to certain measures of explosive power and sub-maximal aerobic capacity; these theoretically beneficial changes were not heart rate, while no change occurred in exercise cardiac output resting, exercise cardiac index and resting heart rate.

**Dintiman**\(^{23}\) studied the effects of various training programme on running speed which were the components of physical fitness. The purpose of the study was to determine whether a flexibility training programme and the combination of both would effect on running speed when used as a supplementary training programme to the conventional method of training sprinters. Results showed that neither the flexibility training programme nor the weight training programme used as supplement to sprint training did not improve running speed, where as both weight training and flexibility training used as supplements to sprint training, increased running speed significantly.

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Gregory\textsuperscript{24} conducted a study to analysis the comparative effects of down hill verses level training circuits on the running speed stride length, stride frequency and leg strength. The subjects were randomly assigned to each of the groups. The treatment period lasted five weeks during which the subjects ran 15 to 40 yards sprint at the beginning of each practice session.

The findings of the study were:

a) The down hill method of training significantly improved the stride length, but it did not significantly increase the running speed.

b) Stride frequency and leg strength did not improve significantly though some improvement was observed.

Gamer\textsuperscript{25} in his study determined plyometric programme was better than a weight training exercise programme in improving leg power, as measured by vertical jump, standing long jump and forty meters sprint ability. The training protocol consisted of plyometric drills two times a week or weight training exercises three times a week for an eight week period pretest and post test assessments were taken. Mean gains from the pre test to the post test for the weight training, plyometric training and control groups weight training, plyometric training and control groups respectively were: standing long jumps: eleven point two centimeters, nine point five centimeters and point five centimetres, vertical jump: two point three, one point seven and point two centimetres and forty metres sprint: point tow one second, point two seconds and point zero three seconds. The gains achieved by both treatment groups were significantly (P<0.05) greater than those experienced by the

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\textsuperscript{25} James A. Gamer, “The effect of weight training and plyometric training on vertical jump, standing long jump and 40 meters sprint” \textit{Dissertation Abstracts International}, 47:8, (February 1987), 2944-A.
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control group, but no difference existed between the gains attained by the two treatment groups. It was concluded that under the delimitations of the study there was no difference between the two programmes in proving the leg power.

Olsen\textsuperscript{26} studied the effect of a set of circuit training programme on strength and muscular endurance of college age male (N = 42) enrolled in weight training classes participated in the study. Pre and Post test for 1RM straight absolute muscular endurance and relative muscular endurance were given for the bench press and leg press. Treatment consisted of two workout session per week of seven weeks. In each session students were requested to complete two set of ten exercises. Both set of exercises were completed before a student moved to the next activity. A work result ratio of 20 sec/10 sec was used. Test retests procedure and pretest and post test means changes were analyzed using Pearson’s ‘r’ and dependent analysis. Mean changes between pre and post test for 1RM strength in the bench press and leg press, and relative muscular endurance in the bench press were significant (P<0.08). No significant change in relative muscular endurance in the leg press (P<0.05).

Devries\textsuperscript{27} formulated the hypothesis that the looseness factor in sprint running would be enhanced through lessening the resistance of antagonistic muscles and their connective tissue by stretching. On the basis of this hypothesis, it was predicted that running times would be improved and metabolic cost reduced as the result of improving joint mobility through stretching. Static stretching was used as a warm up procedure to allow evaluation of a relatively pure flexibility factors as a contribution to muscular


\textsuperscript{27} Herbert A. Devries, “The looseness factor in speed and O2 consumption of an anaerobic 100 yards dash”, \textit{Research Quarterly}, 34 (October 1963), 305.
efficiency or ‘looseness’. Four subjects each run ten 100 yards time trials anaerobically. Five trials followed no warm up and five followed a period of static stretching. Difference in running time and all respiratory measure were small in magnitude and non achieved significance at the 0.05 level.

Haywood, Clarke and Mayhew\textsuperscript{28} observed the development of strength and flexibility in adults in enhanced by training in competitive sports. Much less is known about such physiological changes in young children. The present study compared the effects of training between female gymnastics and swimmers aged seven to twelve years. Anthropometric measures, specific and general strength tests, and flexibility measures were taken. Swimmers were significantly taller, heavier and had greater lean body weight than gymnasts, although there was no significant difference in between the two groups. Waist girth, specific arm pulling, strength, ankle and trunk flexibility reflected possible differential involvement of body areas in the two sports. Participants appeared to maintain flexibility and percentage fat over the seven to twelve years age range, while increasing body size and strength during that time. Involvement in these two sports makes positive contributions towards body composition strength and flexibility in young girls.

Kumar\textsuperscript{29} investigated the effect of break in training on selected motor components of professional students of physical education. The study was conducted on thirty male students of B.P.E. second years ranging in age sixteen to twenty four years of Lakshmibai National College of physical education, Gwalior. After a regular schedule of training and exercise for three


\textsuperscript{29}Ameresh Kumar, “Effect of Break in Training on Selected Motor components of Professional Students of Physical Education,” \textit{Unpublished Masters Thesis}, (Jiwaji University, 1983)
and a half months it was again conducted after twenty one days of break in training. It was found that in case of professional students of physical education, the break in training for short duration would not affect the selected motor components of the body.  

Morgan\textsuperscript{30} studied second and fifth grade students. Students were involved in an eight week, five or ten minute physical fitness programme. Four experimental groups (two second and two fifth grade) and two control groups (one second and one fifth grade) were pre tested and post tested in the nine minute run, sit-ups and the sit and reach. The data were subjected to an analysis of variance to determine if there were significant differences in mean gains between experimental and control groups, between sexes within each group, between five and ten minute physical fitness programme and between second and fifth grade experimental groups. Results revealed significance for three experimental groups in the nine minute run and one experimental group in the sit up test. The only group to show significant difference between sexes is the fifth grade control group, in all three tests. No significance was revealed between the five and ten minute programme or between the second and fifth grade groups. The 0.05 level was used to determine the significance.  

Watt\textsuperscript{31} conducted a study, in that, one group of twenty one subjects were subjected to a developmental course of exercise at the University of Oregon. A second group of seventeen subjects went through a developmental course in which circuit training was used. The subjects were tested in pull-ups, 30 yards shuttle run and 60 second sit ups in test before and after the course. Watt found that significant gains in the physical fitness in

\textsuperscript{30} Loretta Netheston D.A. Morgan, “A study of the effects of two physical fitness programmes on second and fifth grade children in terms of endurance, Abdominal strength and flexibility”, \textit{Dissertation Abstracts International}, 48:3 (September 1987), 3694-A  

\textsuperscript{31} N.S. Watt, “comparison of Two Methods of Physical Fitness Training in low fitness males at the University of Oregon,” \textit{Completed Research}, 4: (1962), 252
the low fitness students can be achieved through both programmes. It was concluded that improvement in the performance of the cardio respiratory test can be increase significantly by the regular developmental course exercises or by circuit training.

**Baquet et al.**[^32], conducted a study on High-intensity aerobic training during a 10 week one-hour physical education cycle: effects on physical fitness of adolescents aged 11 to 16. The aim of this study was to analyse the effects of a high-intensity aerobic training program on different components of physical fitness in adolescents aged 11 to 16 years. The subject was divided into a high intensity (HI) group (243 girls and 260 boys) and a control (C) group (21 girls and 27 boys). HI and C completed a weekly 3 hour physical education (PE) session. Before and after a 10-week period, the two groups performed the European physical fitness test battery (EUROFIT).

During these 10 weeks HI spent one hour out of the three at a specific PE session. These specific sessions consisted of short intermittent exercises (19 seconds) at 100 to 120% of maximal aerobic speed. They showed a significant influence on standing broad jump (2.9%, P<0.05, F=4.85), 20 meter shuttle run (3.8%, p<0.001, F=23.21) and on the maximal distance covered over 7 min (7.6%, P<0.001, F=14.48). For C there was no improvement in Eurofit performances. It was concluded that training at high intensity improves not only children’s aerobic fitness but also performance of standing broad jump. Well-monitored, adequate intensive training is necessary for a more desirable functional development.

Baquet et al.\textsuperscript{33} studied Effects of a short term interval training program on physical fitness in pre-pubertal children. The aim of this study was to analyze the effects of a 7-week interval-training program on different aspects of physical fitness in children who were 8-11 years old. Fortysix boys and 54 girls (9.7 +/- 0.8 years) were divided into an experimental group and a control group. The 2 groups performed selected tests from the European physical fitness test battery before and after training. Training consisted of 2 specific 30-minute sessions per week of short high-intensity, intermittent-running aerobic exercises at velocities ranging from 100-130\% of maximal aerobic speed. After training, the experimental group demonstrated a significant improvement in the standing broad jump (9.6\%, \(p<0.001\), \(F=12.9\)) and 20-meter shuttle run (5.4 \%, \(p< 0.001\), \(F=14.4\)), whereas for the control group, no significant changes were observed. It was concluded that a high-intensity, intermittent-running program improved children’s aerobic performance and explosive strength.

Chatterjee and Bandyopadhyay\textsuperscript{34} studied the Effect of continuous slow-speed running for 12 weeks on 10-14-year-old Indian boys. Endurance training was conducted on a group of 41 East Indian boys aged 10-14 years and was compared with 25 untrained boys of the same age. A continuous slow-running method was adopted for 12 weeks. The intensity of the training was 80-85\% of maximum heart rate and frequency was 3 days per week. The boys were trained for a 1500-m event and therefore they covered three to five times their racing distance. For psychological reasons the training was carried out in a playground. The investigations included different physical and motor fitness tests: measurement of flexibility, agility, speed, leg muscle strength


\textsuperscript{34} Chatterjee S and Bandyopadhyay A, “Effect of continuous slow-speed running for 12 weeks on 10-14-year-old Indian boys”, \textit{British Journal of Sports medicine}, 27:3, (Sep. 1993,) 179-85
etc. Their performance times were also recorded before and after training. From statistical analysis we concluded that this particular type of training programme did not produce and detrimental effects on 19 to 14 year-old boys. On the other hand, this type of training did have some influence on improving physiological parameters in this age group of boys when compared with untrained boys of the same age.

Polman et.al\(^{35}\), conducted a study on Effective conditioning of female soccer players. They compared the efficiency of three physical conditioning programmes provided over a 12 week period (24 h in total) on selected anthropometric and physical fitness parameters in female soccer players. Two of the groups received physical conditioning training in accordance with speed, agility and quickness (SAQ); one group used specialized resistance and speed development SAQ equipment (equipment group; n=12), while the other group used traditional soccer coaching equipment (non-equipment group; n=12). A third group received their regular fitness sessions (active control group; n=12). All three interventions decreased (P<0.001) the participant’s body mass index (-3.7%) and fat percentage (-1.7%), and increased their flexibility (+14.7% and maximal aerobic capacity (VO2 max) (+18.4%). The participants in the equipment and non-equipment conditioning groups showed significantly (P<0.005) greater benefits from their training programme than those in the active control group by performing significantly better on the sprint to fatigue (-11.6% for both the equipment and non-equipment groups versus -6.2% for the active control group), 25 m sprint (-4.4% vs -0.7%), left (-4.5% vs -1.0%) and right (-4.0% vs -1.4%) side agility, and vertical (+18.5% vs +4.8%) and horizontal (+7.7% vs +1.6%) power tests. Some of these differences in improvements in physical fitness between the equipment and non-equipment conditioning groups on the one hand and the active control group on the other hand were probably due to the specificity of

the training programmes. It was concluded that SAQ training principles appear to be effective in the physical conditioning of female soccer player. Moreover, these principles can be implemented during whole team training sessions without the need for specialized SAQ equipment. Finally, more research is required to establish the relationship between physical fitness and soccer performance as well as the principles underlying the improvements seen through the implementation of SAQ training programmes.

Siegler et.al\textsuperscript{36}, conducted a study on Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training-protocol. The purpose of this study was to evaluate changes in soccer-specific power endurance of 34 female high school soccer players throughout a season either with or without an intermittent, high-intensity exercise protocol. Thirty-four female high school soccer players were tested prior to the 2000 fall season and again 10 weeks later. The tests included an abridged 45 minutes shuttle test (LIST), hydrostatic weighing, vertical jump, 20-m running-start sprint, and 30-second Wingate test. The experimental group (EG; n=17, age 16.5 +/- 0.9 years) completed a 10-week in-season plyometric, resistive training, and high-intensity anaerobic program. The control group (n=17, age 16.3 +/- 1.4 years) completed only traditional aerobic soccer conditioning. Statistical significance was set at alpha <0.05. The experimental group showed significant improvements in the LIST (EG = delta 394 seconds +/- 124 seconds), 20-m sprint (EG = Delta -0.10 seconds +/- 1.47 kg) comparing pre-to postseason. This study indicates that a strength and plyometric program improved power endurance and speed over aerobic training only. Soccer –specific power endurance training may improve match performance and decrease fatigue in young female soccer players.

\textsuperscript{36} Siegler J, Gaskill S, Ruby B., “Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training-protocol”, \textit{Journal for Strength and Conditioning Research}, 17:2, (May, 2003), 379-87
Lakomy and Haydon studied the effects of enforced, rapid deceleration on performance in a multiple sprint test. The nature of multiple sprint sports such as soccer, hockey, and rugby is such that deceleration plays an important part in the movement patterns of players during a game and training. The purpose of this study was to investigate the efforts. A group of 18 elite field hockey players (all men) performed a running repeated sprint ability test (6x40 m using maximal effort and departing every 30 seconds.) In one condition, there was no deceleration component (rapid deceleration to a stop with 6 m of the end of each sprint). Sprint times under each condition were compared using a repeated-measures analysis of variance. No significant difference was seen between the 2 conditions for mean sprint times (p>0.05) or for the mean fatigue index (p>0.05). However, results showed a divergent trend, and further analysis extrapolating the data for an increased number of sprints showed that a significant difference (p<0.05) would have been seen at the 11th sprint. Although this study found that the deceleration zone had little effect on the 6-sprint protocol, it was clear that the deceleration component would have shown an effect, giving raise to greater fatigue and slower sprint times, if the number of sprints had been increased. The implications are that the deceleration training should be introduced into general fitness training programs for those competing in multiple sprint sports.

2.5. STUDIES ON SPEED PARAMETER

Milan Čoh, et. al., conducted a research on The Biomechanical Model of the sprint and block acceleration. The study analyzed and identified


the major kinematic parameters of the phases of the sprint start and block acceleration that influence the results of sprint running. The biomechanical measurements and kinematic analysis were performed on the best world’s best sprinter during his preparation for the European Athletics Championship in Goetebourg in 2006. In this competition, Matić Osovnikar won the bronze medal in the 100-metre run and set the Slovenian national record with 10.14 s. The kinematic parameters of the sprint start were established on the basis of a 2-D kinematic analysis, using a high-speed camera with a frequency of 200 frames/sec. The measurements of the block acceleration were made by means of the Opto Track technology and an infra-red photo cell system. The athlete performed five, 20m low-start sprints under constant and controlled measurement conditions. The subject of the study was the set position from the point of view of the height of the total body’s centre of gravity (TBCG), the block time at the front and rear blocks, block velocity, the block face angle, the velocity of the TBCG in the first three meters and the kinematic parameters of block acceleration in the first ten steps. The study showed the following were the key performance factors in the two phases of sprint running: medium start block distance, block velocity, low block face angles, first step length, low vertical rise in the TBCG in the first three meters of block acceleration, contact phase / flight phase index in the first ten steps and the optimal ratio between the length and frequency of steps.

Harris et. al

Harris et. al\textsuperscript{39} conducted research on Relationship between Sprint Times and the Strength/Power Outputs of a Machine Squat Jump. Strength testing is often used with team-sport athletes, but some measures of strength may have limited prognostic/diagnostic value in terms of the physical demands of the sport. The purpose of this study was to investigate relationships between sprint ability and the kinetic and kinematic outputs of a machine squat jump.

\textsuperscript{39} Harris, Nigel K; Cronin, John B; Hopkins, Will G; Hansen, Keir T, Relationship between Sprint Times and the Strength/Power Outputs of a Machine Squat Jump”, \textit{Journal of Strength and Conditioning Research}, 22(3), (May 2008), 691-698
Thirty elite level rugby union and league athletes with an extensive resistance-training background performed bilateral concentric-only machine squat jumps across loads of 20% to 90% 1 repetition maximum (1RM), and sprints over 10 meters and 30 or 40 meters. The magnitudes of the relationships were interpreted using Pearson correlation coefficients, which had uncertainty (90% confidence limits) of ±0.3. Correlations of 10-meter sprint time with kinetic and kinematic variables (force, velocity, power, and impulse) were generally positive and of moderate to strong magnitude ($r = 0.32$-$0.53$). The only negative correlations observed were for work, although the magnitude was small ($r = -0.18$ to $-0.26$). The correlations for 30- or 40-meter sprint times were similar to those for 10-meter times, although the correlation with work was positive and moderate ($r = 0.35$-$0.40$). Correlations of 10-meter time with kinetic variables expressed relative to body mass were generally positive and of trivial to small magnitude ($r = 0.01$-$0.29$), with the exceptions of work ($r = -0.31$ to $-0.34$), and impulse ($r = -0.34$ to $-0.39$).

Similar correlations were observed for 30- and 40-meter times with kinetic measures expressed relative to body mass. Although correlations do not imply cause and effect, the preoccupation with maximizing power output in this particular resistance exercise to improve sprint ability appears problematic. Work and impulse are potentially important strength qualities to develop in the pursuit of improved sprinting performance.

Thomas et. al$^{40}$, studied the Physiological Determinants of 40-Meter Sprint Performance in Young male athletes. This study examined 20 male athletes on a number of physiological variable to determine which may account for the most variation in 40-m sprint performance. The athletes were tested on 40-m sprint, 10-m sprint, a 5-step jump, vertical jump, wingate anaerobic cycle power, and isokinetic peak torque of the knee and hip at

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speeds of 1.05, 3.14 and 7.85 rad. sec and ankle at speeds of 1.05, 3.14 and 5.24, rad. sec. with \( R = 0.897 \) (\( p \leq 0.05 \)) and \( \text{SEE} = 0.151 \) (sec), the 10-m sprint and ankle dorsiflexion peak torque at 5.24 rad. sec were identified as predictors of 40-m sprint performance. With the 10-m sprint removed as an independent variable, stepwise multiple regression was performed again. With \( R = 0.909 \) and \( \text{SEE} = 0.146 \) sec, the 5-step jump, knee flexion peak torque at 7.85 rad. sec, and ankle plantar flexion peak torque at 1.05 rad. sec were identified as predictors of 40-m sprint performance. The results indicate that both 10-m sprint and 5-step jump can be used to predict 40-m sprint performance.

Wisløff, et. al\(^{41}\), conducted a study on Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players.

**Background:** A high level of strength is inherent in elite soccer play, but the relation between maximal strength and sprint and jumping performance has not been studied thoroughly.

**Objective:** To determine whether maximal strength correlates with sprint and vertical jump height in elite male soccer players.

**Methods:** Seventeen international male soccer players (mean (SD) age 25.8 (2.9) years, height 177.3 (4.1) cm, weight 76.5 (7.6) kg, and maximal oxygen uptake 65.7 (4.3) ml/kg/min) were tested for maximal strength in half squats and sprinting ability (0–30 m and 10 m shuttle run sprint) and vertical jumping height.

**Result:** There was a strong correlation between maximal strength in half squats and sprint performance and jumping height.

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Conclusions: Maximal strength in half squats determines sprint performance and jumping height in high level soccer players. High squat strength did not imply reduced maximal oxygen consumption. Elite soccer players should focus on maximal strength training, with emphasis on maximal mobilisation of concentric movements, which may improve their sprinting and jumping performance.

Jansson et. al\textsuperscript{42}, conducted a study on Increase in the proportion of fast-twitch muscle fibers by sprint training in males. Fifteen male physical education students were studied. The subjects trained for 4–6 weeks, 2–3 days per week, on a mechanically braked bicycle ergo meter. A training session consisted of repeated 30-s 'all-out' sprints on a Wingate bicycle ergo meter, on which the brake band of the flywheel was loaded with 75 g kg\textsuperscript{-1} body wt, with rest periods of 15–20 min between consecutive sprints. Thigh muscle biopsies were taken before and after the training period and were analysed for fiber types using a myofibrillar ATPase stain. The proportion of type I fibers decreased from 57 to 48% (\(P < 0.05\)) and type IIA fibers increased from 32 to 38% (\(P < 0.05\)). This study indicates that it is possible to achieve a fiber type transformation with high-intensity training. The effect of two-legged ‘sprint’ training on muscle fiber type composition may be related to a changed pattern of muscle fiber activation (e.g. an increased stimulation frequency). A change in fiber activation frequency may induce an increased synthesis of type II fiber myosin (fast myosin). Hormonal influences such as enhanced adrenergic stimulation of the muscle fibers cannot be excluded as a contributing factor, however.

Wadley\textsuperscript{43} studied on the relationship between repeated sprint ability and the aerobic and anaerobic energy systems. A large number of team games require participants to repeatedly produce maximal or near maximal sprints of short duration with brief recovery periods. The purpose of the present study was to determine the relationship between repeated sprint ability (RSA) test that is specific to the energy demands of Australian Rules football (ARF), and the aerobic and anaerobic energy systems. Seventeen ARF players participated in the study. Each participant was assessed for $V\text{O}_2$ max, accumulated oxygen deficit (AOD), best 20 m sprint time and RSA. The RSA test involved 12×20 m sprints departing every 20 s. When including the work performed during the time taken to decelerate, the test involved a work to rest ratio of approximately 1:3. Total sprinting time and the percentage decrement of repeated sprinting times were the two derived measures of RSA. The results indicate that the best 20 m sprint time was the only factor to correlate significantly with total sprinting time ($r = 0.829$, $P<0.001$) and percentage decrement ($r = -0.722$, $P<0.01$). $V\text{O}_2$ max and AOD were not related to the total sprinting time or the percentage decrement that was produced by the RSA test. This was interpreted to signify that the phosphagen system was the major energy contributor for this test.

Impellizzeri\textsuperscript{44}, (January 2008) Conducted a effective study on “Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players”. The study contains the following. He lower impact on the musculoskeletal system induced by plyometric exercise

\textsuperscript{43}G. Wadley, “The relationship between repeated sprint ability and the aerobic and anaerobic energy systems”, \textit{Journal of Science and medicine in Sport}, 1(2), (2000), 100-110

\textsuperscript{44}ImpellizzeriF.M et. Al., “Effect of Plyometric Training on sand versus Grass on Muscle Soreness and Jumping and Sprinting ability in Soccer Players” \textit{British Journal of Sports Medicine} 42(1), (January 2008); 42-46.
on sand compared to a firm surface might be useful to reduce the stress of intensified training periods or during rehabilitation from injury. The aim of this study was to compare the effects of plyometric training on sand ability. Parallel two-group, randomised, longitudinal (pretest-post-test) study. After random allocation, 18 soccer players completed 4 weeks of plyometric training on grass (grass group) and 19 players on sand (sand group). Before and after plyometric training, 10 m and 20 m sprint time, squat jump (SJ), countermovement jump (CMJ), and eccentric utilization ratio (CMJ/SJ) were determined. Muscle soreness was measured using a Likert scale. The result reveals that no training surface x time interactions were found for sprint time (p>0.87), whereas a trend was found for SJ (p = 0.08), with both groups showing similar improvements (p<0.001). On the other hand, the grass group improved their CMJ (p = 0.033) and CMJ/SJ (p = 0.005) significantly (p<0.001) more than players in the sand group. In contrast, players in the sand group experienced less muscle soreness than those in the grass group (p<0.001). It was concluded that Plyometric training on sand improved both jumping and sprinting ability and induced less muscle soreness. A grass surface seems to be superior in enhancing CMJ performance while the sand surface showed a greater improvement in SJ. Therefore, plyometric training on different surfaces may be associated with different training-induced effects on some neuromuscular factors related to the efficiency of the stretch-shortening cycle.

Little45 (February 2006) studied a research on “Effects of differential stretching protocols during warm-ups on high speed motor capacities in professional soccer players”. The study contains the following. The purpose of this study was to examine the effects of different modes of stretching within a pre-exercise warm-up on high-speed motor capacities important to soccer

performance. Eighteen provisional soccer players were tested for
countermovement vertical jump, stationary 10-m sprint, flying 20-m sprint, and
agility performance after different warm-ups consisting of static stretching
dynamic stretching, or no stretching. There was no significant difference
among warm-ups for the vertical jump: mean +/- SD data were 40.4 +/- 4.9 cm
(no stretch), 39.4 +/- 4.5 cm (static), and 40.2 +/- 4.5 cm (dynamic). The
dynamic stretch protocol produced significantly faster 10-m sprint times that
did the no-stretch protocol: 1.83 +/- 0.08 seconds (no stretch), 1.85 +/- 0.08
seconds (static) and 1.87 +/- 0.09 seconds (dynamic). The dynamic-and
static stretch protocols produced significantly faster flying 20-m sprint times
than did the no-stretch protocol: 2.41 +/- 0.13 seconds (no stretch), 2.37 +/-
0.12 seconds (static), and 2.37 +/- 0.13 seconds (dynamic). The dynamic
stretch protocol produced significantly faster agility performance than did both
the on-stretch protocol and the static-stretch protocol: 5.20 +/- 0.16 seconds
(no stretch), 5.22 +/- 0.18 seconds (static), and 5.14 +/- 0.17 seconds
(dynamic). Static stretching does not appear to be detrimental to high speed
performance when included in a warm up for professional soccer players.
However, dynamic stretching during the warm-up was most effective as
preparation for subsequent high speed performance.

*Young et al*\(^{46}\), conducted study on Specificity of sprint and agility
training methods. The purpose of this study was to determine if straight sprint
training transferred to agility performance tests that involved various change-
of-direction complexities and if agility training transferred to straight sprinting
speed. Thirty six males were tested on a 30-m straight sprint and 6 agility
tests with 2-5 changes of direction at various angles. The subjects
participated in 2 training sessions per weeks for 6 weeks using 20-40-m
straight sprints (speed) or 20-40-m change-of-direction sprints (3-5 changes

\(^{46}\) Young WB, McDowell MH, Scarlett BJ., “Specificity of sprint and agility
training methods”, *Journal for Strength and Conditioning Research*, 15:3,
(Aug 2001),315-9
of 100 degrees) (agility) after the training period, the subjects were retested, and the speed training resulted in significant improvements (P<0.05) in straight sprinting speed but limited gains in the agility tests. Generally, the more complex agility task, have less transfer from the speed training to the agility task. Conversely, the agility training resulted in significant improvements in the change-of-direction tests (p<0.05) but no significant improvement (p<0.05) in straight sprint performance. We concluded that straight speed and agility-training methods are specific and produce limited transfer to the other. These findings have implications for the design of speed and agility training and testing protocols.

2.6. STUDIES ON GENERAL AND COMBINED TRAINING

Kotzamanidis47 (May 2006) conducted a research on ‘Effect of plyometric training on running performance and vertical jumping in prepubertal boys”. The study contains the following. The purpose of this study was to investigate the effect of plyometric training on running velocity (RV) and squat jump (SJ) in prepubescent boys. Fifteen boys (11.1 +/- 0.5 years) followed a 10 week plyometric program (JUMP group). Another group of 15 boys (10.9 +/- 0.7 years) followed only the physical education program in primary school and was used as the control group (CONT group). Running distance (0-10 m, 10-20 m, 20-30 m and 0-30 m), were selected as testing variable to evaluate the training program. The total number of jumps was initially 60 per session, which was gradually increased over a period of 10 weeks to 100 per session. Results revealed significant differences between CONT and JUMP groups in RV and SJ. In JUMP group the velocity for the running distances 0-30, 10-20, and 20-30 m increased (p<0.05), but not for the distance 0-10 m (p<0.05). Additionally, the SJ performance of the JUMP group increased significantly as well (p<0.05). There was no change in either

RV or SJ for the CONT group. These results indicate that plyometric exercises can improve SJ and RV in prepubertal boys. More specifically, this program selectively influenced the maximum velocity phase, but not the acceleration phase.

Christou48 (November 2006) done a experimental research on ‘Effects of resistance training on the physical capacities of adolescent soccer players”. The study contains the following. This study examined the effects of a progressive resistance training program in addition to soccer training on the physical capacities of male adolescents. Eighteen soccer players (age: 12-15 years) were separated in a soccer (SOC; n=9) and a strength – soccer (STR; n =9) training group and 8 subjects of similar age constituted a control group. All players followed a soccer training program 5 times a week for the development of technical and tactical skills. In addition, the STR group followed a strength training program twice a week for 16 weeks. The program included 10 exercises, and at each exercise, 2-3 sets of 8-15 repetitions with a load 55-80% of 1 repetition maximum (1 RM). Maximum strength ([1RM] leg press, bench-press) and jumping ability (squat jump [SJ], countermovement jump [CMJ], repeated jumps for 30 seconds) running speed (30 m, 10 x 5-m shuttle run), flexibility (seat and reach), and soccer technique were measured at the beginning, after 8 weeks, and at the end of the training period. After 16 weeks of training, 1RM leg press, 10 x 5-m shuttle run speed, and performance in soccer technique were higher (p<0.05) for the STR and the SOC groups than for the control group. One repetition maximum bench press and leg press, SJ and CMJ height, and 30-m speed were higher (p<0.05) for the STR group compared with SOC and control groups. The above data show that soccer training alone improves more than normal growth maximum strength of the lower limps and agility. The addition of resistance training, however, improves more maximal strength of the upper and the lower body.

48 M. Christou et. al, ‘Effects of resistance training on the physical capacities of adolescent soccer players” *Journal of Strength Conditioning and Research* 20(4) (November 2006) : 783-791
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.

Markovie\(^{49}\) (May 2007) done a experimental study on “Effects of sprint and plyometric training on muscle function and athletic performance”. The study contains the following. The purpose of this study was to evaluate the effects of sprint training on muscle function and dynamic athletic performance and to compare them with the training effects induced by standard plyometric training. Male physical education students were assistance randomly to 1 of 3 groups: sprint ground (SG; n =30), plyometric group (PG; n = 30), or control group (CG; n =33). Maximal isometric squat strength, squat and countermovement jump (SJ and CMJ) height and power, drop jump performance from 30 cm height and 3 athletic performance tests (standing long jump, 20-m sprint, and 20-yard shuttle run) were measured prior to and after 10 weeks of training. Both experimental groups trained 3 days a week; SG performed maximal sprints over distances of 10-50 m, whereas PG performed bounce-type hurdle jumps and drop jumps. Participants in the CG group maintained their daily physical activities for the duration of the study. Both SG and PG significantly improved drop jump performance (15.6 and 14.2%), SJ and CMJ height (approximately 10 and 6%), and standing long jump distance (93.2 and 2.8%), whereas the respective effect sizes (ES) were moderate to high and ranged between 0.4 and 1.1. In addition, SG also improved isometric squat strength (910%; ES = 0.4) and SJ and CMJ power (4%; ES = 0.4, and 7%; ES = 0.4), as well as sprint (3.1%; ES = 0/9) and agility (94.3%; ES = 1.1) performance. We conclude that short-term sprint training produces similar or even greater training effects in muscle function and athletic performance than does conventional plyometric training. This

study provides support for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

Dodd\textsuperscript{50} (November 2007) conducted a research on ‘Analysis of acute explosive training modalities to improve lower-body power in baseball players”. The study contains the following. Complex training is the simultaneous combination of heavy resistance training and plyometrics. The objective of this study was to test the effects of complex training vs. heavy resistance or plyometric interventions alone on various power-specific performance measures. Forty-five male division II junior college baseball players participated in 3 separate 4-week resistance training interventions. Subjects were randomly assigned to one of three groups. In a counterbalanced rotation design, each group participated in complex, heavy resistance, and plyometric training interventions. Each individual was tested in 20-yd (SP20), 40 yd (SP40), 60-yd (SP60), vertical jump, sanding broad jump and T-agility measures pre- and post- 4-week training interventions. There was no statistical significant difference (p = 0.11) between groups across all performance measures. Review of each distinct training intervention revealed greater percent improvements in SP20 (0.55; -0.49; -012), SP40 (026; -0.72; -1.33); SP60 (0.27; 0.15; -027), standing broad jump (1.80; 0.67; 1.1) and T-agility (2.33; 1.23; -0.44) with complex training interventions than with the heavy resistance or plyometric training interventions, respectively. Plyometric-only training showed greater percent changes in vertical jump (1.90) than with complex (0.97) or heavy resistance training (0.36). The present results indicate that complex training can provide strength and conditioning professional’s equal, if not slightly greater, improvements in muscular power than traditional heavy resistance and plyometric only interventions in moderately trained athletes. Complex training can be another valuable method for short-term power and speed

\textsuperscript{50} D.J. Dodd and B.A. Alwar, ‘Analysis of acute explosive training modalities to improve lower-body power in baseball players”. \textit{Journal of Strength Conditioning and Research} 21(4), (November 2007):1117-1182
improvements in athletes in isolation or in conjunction with other power development methods.

Herrero\textsuperscript{51} (June 2006) conducted a scientific research on "Electromyostimulation and plyometric training effects on jumping and sprint time". The study contains the following. This study compared the effects of four-week training periods of electromyostimulation (EMS), plyometric training (P), or combined EMS and P training of the knee extensor muscles on 20 m sprint time (ST), jumping ability Squat jump (SJ) and Countermovement jump (CMJ), maximal isometric strength (MVC), and muscle cross-sectional area (CSA). Forty subjects were randomly assigned to one of the four treatment groups: electromyostimulation (EG), plyometric (PG), combined EMG, and P (EPG), that took place 4 times per week, and a control group (CG). Subjects were tested before and after the training program, as well as once more after 2 wk of detraining. A significant improvement (p<0.05) in ST was observed after training (2.4%) in EG while a significant slowing (p<0.05) was observed (-2.3 %) in EPG. Significant increases in EPG (p<0.05) were observed in SJ (7.5%) and CMJ (7.3%) after training, while no significant changes on both jumps were observed after training and detraining for EG.

A significant increase (p<0.05) in MVC was observed after training (9.1%) and after detraining (8.1%) in EG. A significant increase (p<0.05) in MVC was observed after training (16.3%) in EPG. A significant increase (p<0.01) in CSA was observed after training in EG (9.0%) and in EPG (7.1%). EMS combined with plyometric training increased the jumping height and sprint run in physically active men. An addition, EMS alone or EMS combined with plyometric training leads to increase maximal strength and to some hypertrophy of trained muscles. However, EMS training alone did not result

\textsuperscript{51} J.A. Herrero et. al., ‘Electromyostimulation and plyometric training effects on jumping and sprint time’ \textit{International Journal of Sports Medicine} 27(7), (July 2006):533-539
in any improvement in jumping explosive strength development or even interfered in sprint run.

Wilson et al\textsuperscript{52} (1994) conducted a study to evaluate the optimal training load for the development of dynamic athletic performance. Three types of resistance training and a control group of recreationally weight-trained individuals were compared on 30 mts sprint, vertical jump without counter movement, maximal cycle test, isokinetic leg extension and maximal isometric tests. The treatments were as follows: (1) traditional weight training, where relatively heavy loads (80-90\% of maximum), where the acceleration and deceleration of body weight was used as the overload in dynamic activities such as depth jumping and bounding; and (3) dynamic weight training performed at the load that maximized mechanical power output. This strategy involves lifting relatively light loads (approximately 30\% of maximum) at high speed. They concluded that dynamic weight training was the only training group that produced significant changes in all measures. The traditional weight training group improved in three and plyometric improved in one.

\textbf{2.7. STUDIES ON 100 METRES RUN PERFORMANCE}

Delecluse et al\textsuperscript{53}, studied the Influence of high-resistance and high-velocity training on sprint performance. The purpose of this study is to analyze the effect of high-resistance (HR) and high-velocity (HV) training on


the different phases of 100-m sprint performance. Two training groups (HR and HV) were compared with two control groups (RUN and PAS). The HR (N=22) and HV group (N=21) trained 3 d wk-1 for 9 wk: two strength training sessions (HR or HV) and one running session. There was a run control group (RUN, N=12) that also participated in the running sessions (1d.wk-1) and a passive control group (PAS, N=11). Running speed over a 100-m sprint was recorded every 2m. By means of a principal component analysis on all speed variables, three phases were distinguished: initial acceleration (0-10m), building – up running speed to a maximum (10-36 m), and maintaining maximum speed in the second part of the run (36-100 m). HV training resulted in improved initial acceleration (P<0.05 compared with RUN, PAS, and HR), a higher maximum speed (P<00.05 compared with PAS), and a decreased speed endurance (P<0.05 compared to RUN and PAS). The HV group improved significantly in total 100 m time (P<0.05 compared with the RUN and PAS group). The HR program resulted in on improved initial acceleration phase (PCO.05 compared with PAS).