CHAPTER II

REVIEW OF RELATED LITERATURE

In the process of prevailing research investigation, sincere attempt was made to broaden the spectrum of knowledge by going through the various sources of literature and acquainting oneself with current ideas of other researchers. This chapter presents a resume of research studies relevant to the present investigation.

Studies on Plyometrics

Olson\(^1\) ascertained that plyometric exercises such as depth jumping and rebounding exercises have been used to increase vertical jumping ability, however, due to the nature of the activity, lower extremity injuries sometimes occur from landing on the hard surface. The purpose of this study was to examine how landing surfaces used in plyometric depth jump exercises affected hip and knee angular kinematics at landing and takeoff, vertical ground reaction forces at landing, and flight times of maximal vertical jumps. Sixteen participants (8 male, 8 female), who were involved in recreational activities, performed ten depth jumps from a 61 cm height. Each

landing, five onto a force platform (hard landing surface) and five onto a 2.35 cm thick foam mat (soft landing surface) placed on top of the force platform were followed by an explosive vertical jump for maximum height. Kinetic data were collected using a Bertec force platform interfaced to the Ariel Performance Analysis System (APAS). All kinematic data were collected using a video camcorder operating at a nominal speed of 60 fps. The kinematic data were digitized, stored and analyzed using the APAS. Maximum angular displacements and angular velocities were recorded for the hip and knee joints. Contact time, flight time, and vertical ground reaction forces were calculated and analyzed. A paired ‘t’ test was used for the statistical analysis with an alpha level of 0.05 for all statistical tests. No significant differences in hip and knee angular displacements or velocities were found between landing surfaces.

Mishra\(^2\) determined that the effect of plyometric training on the development of vertical jumping ability of volleyball players. In keeping with the facilities available to the investigator, the variable, selected for this study was Sargent Jump. The subjects of study were 30 male students playing volleyball in the University and different hostels

of Orissa University of Agriculture and Technology, BBSR and studying in different degree courses during the academic year 1998-99. The average age of the students was 19, ranging from 18 to 20 years. The subjects were equally assigned using random sampling procedure to two groups (one experimental one control). The experimental group participated in the training programme for a period of six weeks. The first group (Group A) performed the plyometric training, the second group (Group-B) which was not allowed to do any exercises served as the control group. The measurement by qualified personnel was performed with standard equipment of the variable for each group of the subjects. The data were taken at the beginning and at the conclusion of an experimental period of six weeks. The training schedule was prepared carefully and systematically, keeping in view of the physical ability of each subject. To find out the significant differences between pre-test and post-test score of group ‘A’ and group ‘B’ data were analysed by applying ‘t’ test. The level of significance was 0.05. The mean, gained by the two groups differed from each other. The finding of the study indicated that experimental group was significantly better than the control group in vertical jumping ability in volleyball as measured by Sargent Jump.
Tamrakar and Brar\textsuperscript{3} carried out study on 30 male students with average age ranged between 15-16 years. They were equally assigned to three groups i.e. two experimental and one control group. The training was given twice a week to traditional training group and plyometric training group for eight weeks. The findings of the study indicated that the plyometric training programme improved leg power.

Schot and Decker\textsuperscript{4} suggested that plyometric training elicits a pattern of forceful, rapid stretching of an active muscle followed immediately by a vigorous contraction of the same muscle. Atleast two training responses occur leading to improved performance: strength increase and neuromuscular adaptations. Depth Jumping is a classic plyometric exercise for which optimal training heights have been sought. The purpose of this study was to examine the response of several variables as drop height changed. Five subjects performed five plyometric jumps from each of five heights (18,36,54,72,90 cm) and also for a counterpart jump (cmj) on a force plateform (1000 Hz sampling rate). A repeated measures ANOVA (t=.05) was used to test


height effects (Tukey post hoc analysis) using subject mean values for each dependent variable. The 54 cm height elicited performance features to a better degree than the others tested.

Chenfu\(^5\) reported the biomechanical variables that characterized advanced and intermediate volleyball players when performing the quick and middle block jumps. The performance of 24 subjects were videotaped in the sagittal plane and digitized with peak performance. Motion Measurement system at 60 Hz. The vertical ground reaction forces during the block jumps were recorded by an AMTI force plateform sampling at 600 Hz. A Two-way repeated measures ANOVA was performed on the dependent variables between skill levels and methods of blocking.

Significant differences were found between the two skill levels on the vertical velocity of the body CG at takeoff, maximum displacement of the body CG, maximum height of the finger tip from the ground, and between two block jumps on the vertical velocity of the body CG at takeoff, maximum displacement of the body CG, maximum height of finger tip from the ground, propulsive phase time,

the hip, knee and ankle angle during the crouch, and maximum vertical ground reaction force.

It was concluded that the vertical velocity of the body CG at takeoff was an important variable for increasing jumping height. The quick block showed a shorter propulsive phase time and a greater peak vertical ground reaction force. The middle block indicated the opposite. It was recommended that the plyometric exercise combined with actual blocking drills should be used during training to improve the blocking ability.

Holcomb⁶ recommended that the plyometric depth jump (DJ) for sports activities such as jumping that require strength and power. The literature revealed that the plyometric depth jump involved the hip extensors, Far-less than does the counter movement jump (CMJ). The purpose of this research was to develop a DJ that would isolate and increase the contribution of the hip extensors as well as the ankle and knee extensors. In experiment I, II college aged males performed the CMJ and DJs while being filmed, and ground reaction

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forces were collected to determine net joint movements, power and work about the joints. The goal was to achieve greater values at the isolated joint than is created with CMJ. All variables were greater with the depth jumps and an ANOVA showed that a total of twenty seven of the thirty three comparisons were significantly different (P≤0.05). The corresponding joint movements for the DJS were significantly greater than for the CMJ. The value for the ADJ was 391 Nm compared to 104 Nm (the KDJ was 292 Nm compared to 148 Nm) and the HDJ was 335 Nm compared to 168 Nm experiment II was used to test the effect of the modified plyometric program on power and the vertical jump. Fifty one college age male subjects were given a pre and post test to determine power and vertical jump height. The modified plyometric program was compared to several conventional programs. Training consisted of three days/week for eight weeks. All groups showed improvements from pre to post tests in both peak power and the vertical jump for the counter-movement test jump, the peak power increased in all training groups but decreased in the control. The vertical jump (control),4.7 cm (CMJ), 3.5 cm (weight training), 6.1 cm (plyometrics) and 4.8 cm (modified plyometrics) Analysis of variance with repeated measures showed no significant differences (p≤0.05).
Levchenko and Matveev\(^7\) study has shown that depth jumping assists in the power development in both preparation and competition period. It should employ in its second half to lift the athlete’s power level. The total number of jump in a two weeks training phase is about 200 to 250. The jumping height was increased step by step from about 40cms.

Bobbert, Huizing and Schenau\(^8\) advocated jumping as an effective exercise for athletes who prepare themselves for explosive activities. When executing drop jumps, different jumping techniques can be used. In this study, the influence of jumping technique on the biomechanics of jumping is investigated. Ten subjects executed drop jumps from a height of 20 cm and counter-movement jumps. For the execution of the drop jumps, two different techniques were adopted. The first technique, referred to as bounce drop jump, required the subjects to reverse the downward velocity into an upward one as soon as possible after landing. The second technique, referred to as countermovement drop jump, required them to do this more gradually.


by making a larger downward movement. During jumping, the subjects were filmed, ground reaction forces were registered and electromyograms were recorded.

The results of a biomechanical analysis show that moments and power output about knee and ankle joints reach larger values during the drop jumps than during counter-movement jumps. The largest values were attained during bounce drop jumps. Based on this finding, it was hypothesized that bounce drop jump is better suited than counter movement drop jump of athletes who seek to improve the mechanical output of knee extensors and plantar flexors. Researchers are, therefore, advised to control jumping technique when investigating training effects of executing drop jumps.

Bobbert, Huijing and schenau\(^9\) also recommended to include drop jumping in training programs. For the execution of drop jumps, different techniques and different dropping heights can be used. This study was designed to investigate for the performance of bounce drop jumps the influence of dropping height on the biomechanics of the jumps. Six subjects executed bounce drop jumps from heights of 20 cm (designated here as DJ 20), 40 cm (designated here as DJ40), and 60

cm (designated here as DJ60). During jumping, they were filmed and ground reaction forces were recorded.

The results of a biomechanical analysis show no difference between DJ 20 and DJ 40 in mechanical output about the joints during the push-off phase. Peak values of moment and power output about the ankles during the push-off phase were found to be smaller in DJ 60 than in DJ40 (DJ20 = DJ 60). The amplitude of joint reaction forces increased with dropping height. During DJ 60, the net joint reaction forces showed a sharp peak on the instant that the heels came down on the ground. Based on the results, researchers are advised to limit dropping height to 20 or 40 cm when investigating training effects of the execution of bounce drop jumps.

Michal\textsuperscript{10} studied forty-five boys selected randomly for the comparative effect of Depth jump and jump squat on vertical jumping ability. Training for 8 weeks (was given thrice a week). The height of the box was 32” and he found that Depth jump and jump squat improved the vertical jumping ability. He also found that Depth jumps

are more strenuous as compared to jump squat and depth jump group has shown higher performance.

Kazol\textsuperscript{11} took 48 college males who were randomly assigned to a dynamic exercise group (N=15) a vertical jump group and a control group (N=16) to study changes in vertical jumping ability over eight weeks. The sargent jump test was used after three periods of instructions and practice at the rest. The dynamic exercise group increased vertical jump by 1.6 inch (P .01), the vertical jump group increased by 7 inches (P .05). Performance changes observed in the experimental group were similar to those reported to previous studies.

Coutts\textsuperscript{12} studied seven members of canada's National Women's Volleyball Team who were tested on vertical jump ability and Margarias test of anaerobic power with results expressed in terms of power (Kg.m/sec) and velocity (m/sec.) or power per unit body weight (Kg./m/kg.sec.). The velocity scores on the two test were not significantly related to each other, and when correlating these values


with height and weight, the relationship between velocity on the Margaria test and height was only significant correlation. Power values on both tests were significantly related to each other as well as to height and weight. The average values of 1.52 m/sec. and 108 kg.m/sec. For the Margaria test and 1.56m/sec. and 110 kg.m/sec. on the vertical jump thus provided normative values on two distinct aspects of leg power per unit body weight for female athletes.

Quarles\textsuperscript{13} conducted a study to compare the 4 sec. in leg power of a rope jumping group of subjects with a stair running group of subjects and found that the stair running group showed a significant gain in leg power, while the rope jumping group did not show any significant gain.

Smith\textsuperscript{14} conducted a research studied the relationship between explosive leg strength and performance in the vertical jump. The leg strength of seventy college men was measured in a position designed to involve the power thrust of the major muscle group used in the vertical jump.


jump. The subjects then performed a modified sargent jump that used no arm snap. Although, the reliability of all measures were high, individual's differences in the ratio of tested strength to body mass showed only a low and non significant correlation with jumping performance. The results are interpreted to support the hypothesis that strength exerted against a dynamometer involves different neuro-motor pattern than strength exerted by the muscle during the movements.

Studies on Weight Training

Williams\textsuperscript{15} analysed if prepubescent males and females benefit from a weight training program, if gender differences exist in muscular strength as a result of a prepubescent weight training program, at what point in a weight training program do strength increases occur, and if a weight training program improves strength more than a general physical education program. Twelve prepubescent males and twelve prepubescent females participated in a seven week weight training program and were compared to an age and gender matched control group who participated in a physical education program for the same time period. The weight training group participated in strength training

\textsuperscript{15} David R. Williams. "Strength Measurements in Prepubescent Males & Females Consequent to a seven week weight training program" \textit{Dissertation Abstracts International} 56: 2 (August 1995): 490-A.
exercises three to four sessions each week. Each group was tested on their six repetition max (6 RM) for upper body strength (bicepcurls) and lower body strength (leg extensors) at the beginning of the program and after three, five and seven weeks of participation. After seven weeks, the male subjects in the weight training group were significantly stronger than the male control subjects (p<.05) and also significantly stronger than all the female subjects in both upper body and lower body strength (P≤.01). After five weeks, the weight training group was significantly stronger than their pre-test and three week participation performances. The weight training group was significantly stronger (P<.05) than the control group on both lower and upper body strength after seven weeks of training the control group did not significantly increase their strength levels during the seven week program. The female experimental group was not significantly different from the female control group throughout the weight training program. However, the female experimental group did show a significant upper and lower body strength increase (p<.01) as a result of the weight training program.

The results of this study demonstrate that prepubescent males and females can make significant strength increases as a result of a weight training program and prepubescent males appear to be stronger than prepubescent females weight training also appears to be superior
to a general physical education program at improving strength in prepubescent children.

Alezo\(^{16}\) was the conditioning coach of Kevin Young, world record holder at 1992 Barcelona Olympics in 400m hurdles. He fully endorsed the weight lifting programme that Kevin was using in his build-up to Barcelona. He used a four-day split as training format. It was reduced to three-day format in last six weeks. The constant communication between coach and trainee and flexibility in programming was considered must for effective training.

Spaniol\(^{17}\) investigated to determine the effects of combining periodized strength training and aerobic training on muscular strength, anaerobic power, aerobic capacity and body composition.

The subjects were 24 class-room volunteers who were randomly divided into two experimental treatment groups and one control group. Group-I performed a three stage periodized strength training programme utilizing free weight squats and bench presses. Group II performed the exact program as that of Group I but upon

\(^{16}\) Bob Alezo, "Weight Training for the 400M Hurdler" Track Technique: 123 (Spring 1993): 3915-3918.

completion was immediately led to the indoor track where they performed a progressive jogging programme for 15-25 minutes utilizing a 65-90 percent target heart rate.

The analysis of data indicated significant differences between the groups in both hip and leg and upper body strength levels. Group I (strength and endurance) improved significantly from pre-test to post-test over Group III (control). No significant differences were found to exist between the groups in anaerobic power, aerobic capacity, and body composition measurements.

Anderson\textsuperscript{18} compared the relationship among isometric, isotonic and isokinetic concentric and eccentric quadriceps and hamstring forces, were measured using a Kin com for each method of strength assessment. Force per body weight (F/bw) data were determined for each subject. The force which was the best predictor for 40-ym dash time was the right peak isokinetic concentric hamstring force at 60 degree/sec (R=570). The force which was the best predictor for agility run time was the left overage isokinetic eccentric hamstring force at 90 degree/sec.

There was no significant (P 0.05) correlation between any measured force and vertical jump. Eccentric muscle force was determined to be no better predictor of general athletic performance than muscle force assessed in other ways. However it may be a better predictor of some component of athletic performance such as agility. Even though there were significant correlation between force variables and performance measures. Prediction equations were formulated for 40 Yd. dash and agility run. It was concluded that because of the limited among of variance in performances, explained by the force variables, force measures from a clinical tool such as the kin com should be used to meet clinical goals and not be interpreted as a measure of functional capacity of readiness.

Taewon\textsuperscript{19} investigated the effects of interval training on dynamic muscular strength, power and cardio respiratory function in male college students. The training was carried out for 60 minutes twice a week and continued for six weeks. From the statistical evaluation of the results it was evident that interval weight training leads to increase in strength and power but not much effective to

improve cardio-respiratory function. Six weeks of interval weight training is superior to circuit weight training in producing squat strength.

Marshall\textsuperscript{20} conducted a study to determine the effect of eccentric work and its comparative contribution in the development of power and strength. Three different strength training techniques were used and compared. Three groups of untrained subjects (male and females N=13) were trained for ten weeks using on the three prescribed methods. Pre-test and post test measures were taken for muscle girth, body fat percentage, performance on cybex at three different speed of arm flexion and leg extension and 1-RM strength tests using nautilus machines.

Sanders\textsuperscript{21} determined the effect of 10 week resistance training exercises on development of strength, muscle girth and body composition of a group of college women. 42 college women participated in the study 20 serving as control group and 32


participating in 10 weeks of progressive training. Eight basic strength development exercises, shoulder press, bench press, leg press, arm curl, knee extension, knee flexion, pulley-behind the neck and sit-ups were used in the programme. Data pertaining to these were analyzed using t-test and analysis of co-variance. The results of this study revealed significant increases in strength within the experimental groups on six of the eight strength tests.

Steven\textsuperscript{22} compared the effects of fast and slow speed isokinetic training on strength, endurance and muscle fibre composition. Ten subjects trained on one leg using slow contraction (48 degree per second) and the other using fast contraction (192 degree per second) three days/week for 9 week dynamic strength of the leg extensor muscle was measured at 8 velocities ranging from 120 degree per second to 264 degree per second, with isometric strength determined at 72 degree from full extension. A two-minute endurance test was given before and after the training period at both the slow and fast training speeds. Both legs showed significant increases in strength, at all speed tested, with the slow leg showing greater improvement at 48 degree per second and 158 degree per second endurance and time of peak torque.

changes were similar in both leg with the fast leg showing greater tendency for greater improvements. Muscle fibre composition was not significantly altered by either training programme. It was concluded that strength and muscular endurance gains in untrained individuals are more related to total work than training velocity.

Razzook\textsuperscript{23} tested the effects of a standard weight training program and a dynamic weight lifting program on the development of muscular strength as measured by 1 RM on the bench press test, muscular power as measured by the vertical jump test, and the muscular endurance as measured by the greatest number of repetitions in the full squat test which could be done with fifty percent of the subjects body weight. Forty-four male college students were the subjects divided into two groups and randomly assigned to one of the two training programs. The standard weight-training program consisted of five exercises which were the jumping squat, wide bench press, dumb bell press, full squat, and two arm curl. The dynamic weight lifting program was comprised of the same exercises that were used in the standard weight training program with one extra exercise referred

to as the two-arm clean and jerk. All subjects performed three days weekly for a nine-week training period. After pre-tests were administered, subjects were tested after three, six and nine weeks of training. Both groups had significant improvement in muscular power, muscular endurance and the selected muscle girths after nine weeks of training.

In comparing the two groups, a highly significant difference was found in muscular strength favouring the dynamic weight lifting group.

Silvester\(^{24}\) compared the effect of variable resistance and free hand weight training programmes on leg strength, vertical jump and high circumference. Seventy nine male students were assigned randomly to four groups. Pre mid and post tests were administered on various muscle groups. Through an ANOVA and Newman-Kuels sequential range test significance of the difference was found and it was concluded that all the training systems caused significant strength gains in all strength measures.

Seager\textsuperscript{25} compared the effectiveness of isokinetic and isotonic exercise programmes. The study investigated whether the programme would result in greater retention of strength and if an abbreviated Isokinetic programme would be effective in maintaining strength. 30 subjects of varsity baseball players were randomly assigned to one of three exercise groups of ten each. Group one performed isotonic exercises for six weeks prior to the baseball season but had no maintenance programme during the season. Group two performed Isokinetic exercises for six weeks prior to the baseball season but had no maintenance programme during the season. Group three performed the same isokinetic exercise prior to the baseball season but had a maintenance programme of two days a week during the season. Data was analyzed using ANOVA for repeated measures and t-test whenever necessary. While all groups increased in strength from the pre-test to the six week tests, there were no significant difference found between groups in the five strength tests.

Micheal\textsuperscript{26} determine the effects of a concentric and an eccentric training programme on the vertical jump and also on concentric and eccentric leg strength of the quadriceps femoris muscle group. Subjects enrolled in collegiate PE classes were used. 2 groups, 1 concentric ($N=14$) and 1 eccentric ($N=14$) trained 3 days/week for 8 weeks and were pre and post tested on all 3 dependent variables. The vertical jump was also tested every 2 weeks throughout the training programme. Dependent ‘t’ test within group for all dependent variables showed that the gain were significant. The concentric group gains on the concentric leg strength variable were significant at the .01 level. ANOVA of the between group XS on the concentric leg strength variables was not significant. The eccentric leg strength variable indicated a significant F. A 2 x 4 repeated measure ANOVA of the X vertical jump scores indicated there was no significant difference in training programme, there was a significant difference in median vertical jump scores across the 4 testing periods, a trend analysis indicated a highly significant linear trend across the 4 testing periods but no significant quadratic or cubic trend and the interaction of treatment trials were significant.

Otenghen\textsuperscript{27} selected 48 varsity and second team intercollegiate Volleyball players from four Universities who were randomly assigned to either a control or isokinetic training group. After performing three sets of 10 kg. press repetition maximum, three days per week for eight weeks, on isokinetic speed controlled machines, the groups were compared on a strength measure and on Vertical jump performance. According to the group to which they were assigned (control, fast speed or slow speed) subjects from all schools were combined according to treatment effect for comparison purpose on the Vertical jump. For the strength measure, the combined slow or fast speed subject groupings formed an experimental treatment group which was compared to a combined control group. A two way ANOVA with repeated measures on 1 factor was applied to data obtained on the jump and each of the strength measures. The slow and fast speed isokinetic groups were significantly superior to the control group on vertical jump performance. The slow speed isokinetic group improved significantly more in strength than did the control group.

Studies on Weight Training

Staheli\textsuperscript{28} conducted a study on comparison of the effects of isokinetic and isotonic exercise methods on leg strength, vertical jump and thigh circumference. The isokinetic methods employed the Mini-Gym power racks. The isotonic method employed the Olympic barbell and universal Gym leg press machine. Eighty male students were assigned randomly into four treatment groups as follows: Group A; power racks, Group B; leg press’ Group C; squat and Group D; control. Pre and post tests were administered on right and left knee extension strength, right and left hip extension strength, vertical jump and right and left thigh circumference.

Through an analysis of variance and Tukey’s studentized range test significant differences were found and the following conclusion were drawn: (a) The power rack, leg press and Olympic barbell group each showed significant improvement in all criterion measures; (b) No significant differences were detected among the leg press, Olympic barbell or power rack groups.

Mckethan\textsuperscript{29} studied the effect of a training programme involving isometric, isotonic and combination of isometric and isotonic on quadriceps strength and vertical jumping ability. 24 male subjects were assigned to 3 experimental and control group. Vertical jumping performance was evaluated by the jump and reach procedure and cable tension tests were used to measure quadriceps strength. The training for the isometric group involved 16 seconds maximum isometric bout at each of $90^\circ$, $110^\circ$ and $130^\circ$ of knee extension. The isotonic group trained by utilizing maximum knee extension. The combined group trained by performing an isometric contraction at $90^\circ$ and then completing the knee extension against isotonic resistance. The quadriceps strength of the isometric exercise group was greater than that of the control group. Other among groups companions were non-significant, within group gains in quadriceps strength occurred for each of the three training procedure and there were no difference among or within the groups in relation to vertical jumping ability.

Ferris\textsuperscript{30} conducted a study to find out the effect of eccentric and concentric – eccentric contraction on measure of static and dynamic knee flexion strength as well as the 40, 50 and 60\% relative static and dynamic knee flexion endurance on 28 male physical education majors ranging from 19 to 23 years of age. Subject were assigned to 2 groups who were trained using eccentric and concentric eccentric contraction training for eight weeks followed Delorme’s 3 set, 10 repetition 3 times/week progressive resistance exercise routing. The only effects of either programme occurred on 5 of 6 measures of relative static endurance whereas eccentric contraction training and concentric-eccentric contraction training did not differ from each other in producing changes on knee flexion measures of static strength, dynamic strength and static and dynamic muscular endurance.

Teston\textsuperscript{31} conducted a study on male subjects from non major physical education activity classes at Weston Illinois University, who were divided into a training and control group. Subjects were tested for vertical jumping ability and for leg strength measures at the beginning


and following a six week training programme. The training group executed fifteen leg extension isokinetically on two super mini gyms four times weekly, while control group did not participate in any training programme. Results of a t-test for independent sample indicated gains in strength and vertical jump for the training group. The control group had gains in strength but not in vertical jump. The differences between muscular strength gains of the two groups was in favour of the training group.

Philip\textsuperscript{32} studied the electromyographical analysis of specific muscles while used in performing selected isotonic weight training activities. The result of the study indicated that the muscle training of one muscle group increased the strength of the trained muscle and also that of the antagonist muscles. It was apparent that muscle which function antagonistically may contract simultaneously and muscle which acts as agonist, antagonists and stabilizer may be voluntarily and intermittently contracted during a specific activity.

Wilcox\textsuperscript{33} conducted a study on comparison of two weight training methods designed to develop leg strength. The purpose of this study was to compare a vertical leg press method of developing strength with a method utilizing bench squats, on selected college male students. The subjects were divided into two groups, Group-I utilized a vertical leg press machine and Group-II used bench squats. Each group met twice a week for 50 minutes over a ten weeks period. The pre-test and post-test mean difference between groups differ significantly favouring Group-I. In the vertical leg press method with respect to total leg strength and vertical jumping; the improvement of Group-I was statistically significant after beyond the .01 level of confidence, vertical leg press method of developing strength produced significant improvement in total leg strength and vertical jumping over a method utilizing bench squats.

Langton\textsuperscript{34} investigated the relative effectiveness of eccentric versus concentric strength training procedures and changes in static strength associated with changes in Reaction time and Movement time,


Male college students (N=78) were divided into three groups: concentric, eccentric and control. No differences existed between the concentric and eccentric group where as significant differences existed between the control; group and each of the experimental group on following parameters: movement time, static strength at 110°, static strength at 135° and static strength at 160°. Concentric and eccentric contraction training were both effective means improving static strength.

Danielson\textsuperscript{35} compared three groups of ten Universities of Alberta participated in and completed a training and testing programme over a period of nine weeks, seven weeks serving as training sessions. Training occurred three times a week or an average. Isometric training was found most advantageous in improving strength measured concentrically, eccentrically and isometrically. Specificity of training effect was not observed.

Laycoe\textsuperscript{36} studied the effect of isometric and eccentric strength training programme on isometric leg strength. Forty five subjects were divided into three groups, matched according to initial isometric leg strength. One group was a non training control group, the second group trained eccentrically and third group trained isometrically. The training was three days per week for six weeks. Both the eccentric and isometric group showed significant increase in isometric leg strength over the control group but there were no difference between the two exercise groups.

Dufty\textsuperscript{37} Screened male freshman non-wrestlers (N=24) enrolled in wrestling classes. They were taught the long set-out, the takedown drop, and the stand-up wrestling maneuvers. Once maneuvers were learned the subjects were equated into 2 groups on the basis of explosive leg power test scores. For 20 sessions, the experimental group participated in a selected explosive weight-training program in addition to their wrestling class, while the control group participated only in their regular wrestling class. Statistical analysis of mean gain or


loss in inches for the explosive leg power test and the mean gain or loss in .01 second for the performance time of the 3 selected wrestling maneuvers was investigated. Results indicated that the experimental group did significantly improve in explosive leg power.

Gowin\textsuperscript{38} reviewed the effects of two selected weight training programs on strength index. 21 subjects participated in one repetition maximum weight load program and 17 subjects were placed in a 20 sec. Timed circuit weight training group. It was theorized that because the timed-circuit program utilizes less time and less resistance it could be an effective off-season strength program, if strength gains were similar to the more cumbersome program. The modified Roger's Physical Fitness Index Test was used to measure strength. It was concluded that both weight training programs will improve the development of muscular strength and there was no difference in the development of strength between the two programs.

\textsuperscript{38} Albert C. Gowin, "The Effects of Two Selected Weight Training Programs on Strength Index." Completed Research in Health, Physical Education and Recreation: 11 (1969): 205.
Fisher\textsuperscript{39} studied the comparison of isometric, isotonic and power training in the development of muscle strength. 99 Junior High School boys were divided into three equal groups within classes to compare strength development by a 1-RM isotonic programme, 6 sec. Isometric contractions, and power movements where maximum loads were lifted through a range of 6-8 inches. The 1-RM programme and power movements were equally effective in increasing strength and both were significantly better than isometric exercises.

Morris\textsuperscript{40} conducted the study in an attempt to determine the comparing effects of isometric and isotonic weight training methods, used as supplement to interval distance running training of the quadriceps muscle group and on performance in the middle distance running event. Four groups of thirty subjects each were obtained on the basis of sampling by random selection and random assignments. After eight week training programme the result showed that both isometric and isotonic weight training improved quadriceps strength and middle


\textsuperscript{40} Mckinley William Morris, “The Effect of Isometric and Isotonic Weight Training Exercises Upon Quadricep Strength and Performance in Middle Distance Running Event.” Dissertation Abstracts International: 28 (June 1969): 4309-A.

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distance running time more than an unsupplemented interval middle distance running training programme. Further the result indicated that isometric weight training as a supplement to interval running training increased the strength of the quadriceps muscle group as well as middle distance running time more than the isotonic training programme, when used as supplement to interval running training.

Boschs\textsuperscript{41} studied the subjects, trained three times weekly performing leg squat exercise to a position where the upper legs were parallel to the floor, followed by the return to erect position. The experimental subjects (N=22) exercised with weights on their shoulder, while the control subjects (N=24) exercised without weights. The vertical jumping height was measured. A leg dynamometer measured isometric leg strength. A significant improvement in both sargent jumping and leg strength was shown for the experimental subjects. The control group did not improve in either test.

Charles\textsuperscript{42} provided definite evidence of the effect of selected explosive Weight training exercises upon leg strength, free running speed and explosive power. An experimental group of 20 freshman male volunteers were selected randomly from trampoline and handball classes. The experimental group underwent a 5-week explosive weight training program with four sessions per week and three circuits of exercises per session. The groups were tested before and after the program. The experimental group made significantly greater improvement in leg strength, but not in running speed or explosive power.

Guess\textsuperscript{43} tested sixty variety football players in pre-conditioning weight training during the spring and summer months. Of these individuals, 28 participated in a heavy resistive exercise program once per week during the football season. The remaining 32 had no heavy resistive training. Results indicate that regular football practice will not maintain strength development during the pre-season conditioning


\textsuperscript{43} Liles Clay Guess. “A Comparison of Two Training Programs for Maintaining Increased Muscular Strength Developed During an Off-season Conditioning Program.” Completed Research in Health, Physical Education and Recreation: 10 (1968): 117.
program but such practice should be supplemented by heavy resistive exercises.

Misuradze\textsuperscript{44} established the relative effectiveness of selected training programs on the improvement of the vertical jumping ability of Junior High School Boys. Students from a grade 7 Physical education class (\(N=45\)) were divided into three equated groups on the basis of jumping ability and then underwent 12-weeks programs of progressive weight training special calisthenics, and routine exercise. Both experimental groups improved significantly at the 0.05 level over the routine exercise groups with a \(t\) for the weight training group of 2.06 and a \(t\) for the special calisthenics group of 2.21. But the difference in improvement for the two experimental groups was not significant.

O’shea\textsuperscript{45} undertaken a study to determine the effects of a six week progressive weight training programme on the development of strength and muscular hypertrophy, using one exercise, the deep knee bend, with varying repetition. Thirty students were chosen by random

\textsuperscript{44} Paul J. Misuradze, “The Relative Effectiveness of Selected Training Programs on The Improvement of The Vertical Jumping Ability of Junior High School Boys.” \textbf{Completed Research in Health, Physical Education and Recreation}: 9 (1967): 132.

sampling from beginning weight lifting classes at Michigan State University following a two weeks conditioning period the subjects were divided into three groups of ten each for the controlled training period. The programme were as follows: Group A – 3 sets of 9-10 repetitions, Group B- 3 sets of 5-6 repetitions and Group C- 3 sets of 2-3 repetitions. Individual in each group handled maximum weight loads for the number of repetition each was required to perform. The effectiveness of the programme was determined by three measurements: (a) thigh girth, (b) dynamic strength as measured by one RM on the deep knee bend and (c) static strength as measured on the dynamometer. The results were graphically analysed and percentages calculated. The data were also statistically treated using analysis of covariance. No significant differences were found between the three systems of training. All training procedures resulted in the improvement of static and dynamic strength.

Conrad\textsuperscript{46} compared the effect of Skill practice sessions on Vertical jumping ability. Varsity and Junior varsity players (23) from a High School Basketball team were divided into a weight group of 11 who performed Dead lift, knee bend and heel raise exercises and an

exercise group of 12 who spent an equal amount of time practicing the Vertical jump. Three times a week for 6 weeks prior to the basketball season. The sargent jump was used to measure vertical jumping ability before and after the training program. Each group mean increased 2 inches or slightly more but F-ratio of 0.56 from analysis of covariance indicated no difference between the effects of the treatment.

Blucker$^{47}$ randomly selected 29 men and assigned them to physical education measure, exercise measure and control group. Either leg strength was tested with a dynamic vertical jump test, running speed with the especially designed electronic times. The exercise group practice leg strengthening exercise three times weekly for four weeks with progressively repetition but has no significant effect on jumping ability of running speed. Leg strength has not correlated significantly with vertical jump and jumping speed in either test.

Rallis$^{48}$ graded 11 boys in Physical education classes were measured in flexibility, agility, speed, muscle power and endurance of


the arms (1-minute push-ups) and muscle power and endurance of the legs (1-minute squat jumps) before and after 8 weeks participation in isometric, weight training or regular physical education programs. The following conclusions were based on significant t-ratios: Weight training was superior to regular physical education for improving muscle power and endurance of the arms and legs; isometric training was superior to the other programs for improving muscle power and endurance of the arms.

Bangerter\textsuperscript{49} investigated to determine what relative contribution each of the three components of the lower extremities made to the vertical jump. A jump reach form of the vertical jump with a reliability coefficient of 0.925 was of the three components of the leg in isolation and weekly work load for progressive resistance exercise programme were used to validate strength gains.

Tony\textsuperscript{50} conducted a study on comparison of the effects of selected exercise, isometrics and isotonics on explosive power and leg strength. Dynamometric leg strength and sargent jump tests were given to 22 Springfield College freshmen basketball candidates who were randomly divided into three groups that practiced separate exercise programme three times a week for four weeks before being re-tested. Group A with eight subjects practiced squat jump, back board touches, run in place and jumping rope. They increased 40 pounds in leg strength and 9” in jumping, on the average. Group B (75) practiced isometric heel raised and three quarter knee bends and increased 43 pounds and 1.2” in jumping. Group C (75) with isotonic heel raises and three quarter squats increased 151 pounds and 1.6”. Analysis of covariance indicated that the mean gains were not significant at the .05 level.

Thorson\textsuperscript{51} compared the effect of selected exercise programs involving force-stretch training and weight training in the development of leg power. Thirty six male students were randomly assigned to the


forced-stretch group, weight training group and control group. Data were collected before and after five weeks of training. An ANOVA was used to determine the significance of differences between the groups and a ‘t’ was used to determine significance of changes within the group. No significant differences were observed in leg strength among the members of the forced-stretch group and weight training group.

Marley\textsuperscript{52} studied the comparative effectiveness of isometric and isotonic exercise in the development of muscular strength, endurance and girth. Three groups were used, one group trained with isometric exercises, the second group used isotonic exercises and the third group served as control. Subjects were tested several times before and after the ten weeks training programme. Isometric and isotonic exercises appeared equally effective in developing strength but isotonic exercise was more effective in developing muscle size, although size as measured was not proportional to strength.

Berger\textsuperscript{53} conducted a study on the effect of dynamic and static training on vertical jumping ability. The purpose of the study was to determine the effects of strength improvement on vertical jump ability. Eighty-nine male college students participated in four different training programme. Group-I (N=29) trained with the 10-RM, Group-II (N=20) with 50 to 60 percent of the 10-RM for ten repetitions of jumping squats, Group-III (N=21) trained statistically, and Group-IV (N=19) trained by jumping vertically. Training occurred three times weekly for seven weeks. Vertical jumping height was determined before and after the seven week training period. The group that trained dynamically improved significantly more in vertical jumping.

Berger\textsuperscript{54} conducted a study to determine the optimum number of repetition with which to train for quickest strength improvement. Nine groups consisting of a total of 199 male college students were tested before and after 12 weeks of progressive resistance exercise. Each group trained differently in repetition per set. Resistance employed were 2 RM, 4 RM, 6 RM, 8 RM, 10 RM and 12 RM for one set. The optimum number of repetition was found to be between 3 and 9.


Kerr\textsuperscript{55} carried out a study on the effect of weight training on jumping ability of high school athletes and non-athletes. Forty eight subjects were divided into three groups on the basis of age, weight and height by means of Macloy classification index. The weight training programme was conducted for a period of 12 weeks. The experimental groups achieved greater gain than the control group which indicated that heavy resistance had no effect upon the jumping ability of high school basketball players and non-athletes. No significant difference in improvement was found between the skilled and unskilled performer in jumping ability.

James\textsuperscript{56} revealed that the general problem was to compare the effectiveness of a progressive weight training program and a required physical education program for high school boys in the same institution in the specific areas of strength, endurance, reaction time and balance. The method of study was experimental. A general conclusion was that progressive weight training when added to a physical education


\textsuperscript{56} Woodward James, “Progressive Weight Training in Physical Education.” Completed Research in Health, Physical Education and Recreation: 2: 381 (1960): 70.
progressive weight training when added to a physical education program significantly aided development of high school boys in strength, endurance, reaction time and balance.

Capen\textsuperscript{57} opinionated that whenever weight training is discussed, it almost invariably gives rise to the expression of extremely controversial opinions. Its promulgators may go so far as to claim it a panacea of all ills, while its denunciators may not hesitate to set forth its deleterious effects.

Haffman states that weight training is the most effective form of physical training for both visceral, skeletal and muscular development. He believes that exercise with weights produces an optimum physical condition in a minimum of time. Two groups of students were used in this study, one group which referred as Group A, was a weight training class of sophomores. The other group was a conditioning class of freshmen at the same university. Both groups met twice a week for eleven weeks. Group A’s forty-minute class periods were devoted wholly to weight-training exercises. Group B participated for forty minutes each period in a strenuous conditioning course. Both the groups A and B increased in weight, muscular strength, muscular endurance,

Circulo-respiratory endurance and athletic power events with one exception that group B failed to improve in standing broad jump.

Chui\textsuperscript{58} demonstrated the effect of systematic weight training on athletic power. Two groups of subjects were used in the study. One Group A of twenty-three subjects performed the weight training exercises two or three times a week for one hour each period. The other Group B which was composed of twenty-two subjects did no weight training exercises. The data obtained from this study and the implications drawn from the data indicated that the subjects of Group A seemed to increase the amount of potential power. Through systematic weight training exercises, whereas, the subjects of Group B did not show such consistent increases. Power being force times velocity, in the human body is apparently limited by the muscular velocity. The greater the speed of contraction, the more force is required to overcome the viscosity of the muscles. With an increase in strength however more force can be used to overcome the viscosity of muscle and to force the maximum velocity to higher levels.

\textsuperscript{58} Edward Chui, "The Effect of Systematic Weight Training on Athletic Power." \textit{Research Quarterly} 21; 1 (1950); 188.
Studies on Plyometrics and Weight Training

Stanley\(^{59}\) designed this study to investigate the ability to improve vertical jump and thirty-meter sprint speed resulting from a plyometric workout subsequent to an isotonic resistive squat weight training workout within a workout unit. The subjects participating in this study were taken from Texas A & M University – Commerce weight training classes (Groups A,B,C and D). The eight-week training program consisted of three treatment programs and one control factor prescribed as follows: Group A- depth jumps; Group B- isotonic squat program; Group C- depth jumps subsequent to squats and Group D-control. The standing vertical jump test and thirty-meter sprint were two related measurements used for determining power and speed.

It was concluded that a plyometric program subsequent to a resistive squat program within a workout unit has a significant effect on improving vertical jump and thirty-meter sprint. Squats displayed a significant effect on improving vertical jump and thirty-meter sprint. Plyometrics trained independently showed significant improvements in vertical jump and no significance in thirty-meter sprint. The combined squat and plyometric program reported greater improvements.

McGilvray and Haslam\textsuperscript{60} revealed the effects of supplemental resistance and plyometric training program on a vertical jump and flexibility performance of active female dancers. The effects of the training program on three flexibility measurements and a thigh circumference measurement were also investigated. It was hypothesized that the supplemental training program would increase the vertical jump height of the experimental dancers without producing unwanted effects on flexibility and limb size. Sixteen female participants participating in a college dance program were assigned to an experimental or control group. Each experimental participant was tested on each of the five variables before and after the eight week resistance and plyometric training program and each control participant was tested before and after the training period. Eight experimental participants regularly performed squats, dead lifts, depth jumps, double leg hops, double tuck jumps, and stretching exercises. The effects of the training and control condition of the five variables were determined by comparing initial and final test scores. Significant differences (p<.05) were observed between initial and final scores of the experimental group for three of the five variables measured. Vertical jump height increased a mean of 1.3\textdegree. Hip flexion increased by 17.4\textdegree.

Hip abduction at 90° increased by 8.1°. No significant differences (p<.05) were observed between initial and final values for any of the five variables measured on the control group.

Korchemny⁶¹ the coach of Valeri Borzov, famed Russian sprinter formed a training program for speed development. It was specific and properly arranged training menu with a variety of drills in the mode of strength and speed development, the resistance training drills, stick drills, eccentric strength and plyometric drills were given due weightage. It was established that combinations of more specific assignments, properly arranged in the graining program can enhance the development of specific skills and athletic abilities.

Dutko⁶² conducted a study, the purpose of which was to compare two progressive strength training protocol, a plyometric exercise protocol and two flexibility protocols for improving the strength and flexibility of the quadriceps and hamstring muscular complex of high school weight training students. Sixty men 16-18


years of age volunteered for six weeks, 3 days a week, quadriceps and hamstring muscular complex strength and flexibility study.

All training protocols significantly increased left quadriceps, left hamstring strength. However, the flexibility protocol static stretching was more effective in producing strength of hamstring.

Briezer and Korchemny⁶³ Ex-Soviet Coaches examined 400 meter hurdles for women. While preparing the training load of Anna Ambraziene, who ran 54.02 in 1983, resistance training, weight lifting and bound training were exclusively involved.

Kritpet⁶⁴ investigated to examine the effectiveness of a six week strength training programme consisting of squat and plyometric exercise on vertical jump performance, static and dynamic muscular strength and muscular power production in college age adults. Fifteen male and two female college students served as subject for the study. Nine subject trained only with squat exercises, eight subjects trained with combined squat and plyometric exercise. All subjects trained


twice a week for the six weeks. A pre-test, post-test randomized group design was used for this study. The results of the training programme indicated a significant mean increase from pre-test to post-test for the vertical power jump within the combined squat and plyometric training. Static strength significantly decreased from the pre-test level to the post-test level within the squat training programme. Hamstring strength and hamstring power were significantly different within both training programmes. There were no differences in the gain achieved by the two training programmes.

Gamer\textsuperscript{65} determined if a plyometric exercise programme was better than a weight training exercise programme in improving leg power as measured by vertical jump. Standing broad jump and forty-meter sprint ability. The training protocol consisted of plyometric drills two times a week or weight training exercise three times a week for eight week period. Pre-test, mid-test and post-test assessments were taken. Mean gain from the pre-test to post-test for the weight training, plyometric training on control group respectively were: standing jump 11.2 cms, 9.5 cms. And 15 cms; vertical jump 2.3 cms., 1.78 cms and

2.50 cms and 40 meter sprints; .211 sec., .20 sec. and .30 sec. The gain achieved by both treatment groups were signification (p .05) greater than those experienced by control group, but no difference existed between the gains attained by the two treatment groups. It was concluded that there is no difference between the two programmes in improving leg power.

Clutch and Wiltor\textsuperscript{66} studied the effect of depth jumps and weight training on leg strength and vertical jump. Two experiments were described in which the effectiveness of the exercises were examined. In experiment undergraduate students in beginning weight training classes trained with three different jumping programme-(1) maximum vertical jumps, (2) 0.3 meter depth jumps and (3) 0.75 meter and 1.10 meter depth jumps. In addition all groups also lifter weights. In experiment 2, a weight training class and a volleyball team at Brigham Young University, Hawaii were divided into two groups. One group lifter weight and performed 0.75 meter, and 1.10 meter depth jumps. The other group only lifter weights. In experiment one, three training programmes resulted in increase in one repetition maximum (1 RM), squat strength isometric knee extension strength, and in vertical jump.

however, there were no significant difference between treatments. In experiment two, all groups made significant increases in vertical jump, except the group of weight training lifter, who did no jumping. It was concluded that depth jumps are effective not more effective than a regular jumping routine.

Stuart and Larry\(^6\) selected forty-eight college male volunteers and were randomly assigned to one of three groups. Each group was randomly assigned to one of three treatments. Group-I trained with isokinetic exercise, Group-II trained with plyometric exercise, and Group-III was control. Subjects in both experimental groups trained three times per week for eight weeks. The plyometric group performed three sets of ten repetition per set of depth jump from a height of 34 inches. Prior to and at the end of training period all subjects were given a vertical jump and reach test. Covariance analysis was used to compare to post-test scores with the effect of pre-test difference removed. Result showed that both the training group improved significantly in vertical jump capacity however, no significant difference exist between training groups.

Fitness and Amateur Sports Directorate\textsuperscript{68}, Department of National Health and welfare, Canada recommends Box jumping exercises in the training, to strengthen the knee, hip, back, abdominal and particularly ankles. Though weight training can be a valuable asset the explosive and rhythmical movements required are best achieved through combining weight training with special jumping exercise (Box jumping exercise) performed on soft surface.

Don\textsuperscript{69} conducted a study on effect or weight training and rebound training on performance in the vertical jump. Three groups each of six boys were equated on the basis of an initial sargent jump test, height and weight. One group did weight training three days a week with three sets of 5-10 repetitions maximum. One group did rebound training three days a week. Both groups joined the group with physical education classes five days a week on their off days. In eight weeks, the present gains in vertical jump were respectively 7, 21, 7 but none of the differences between or within the group was significant.

Summary of Literature Reviewed

The extensive and thorough review of literature has lead research scholar to conclude that the training protocol for strength and explosive power is generally composed of weight training. Whereas, recently it has been used in combination for strength and explosive power as well as for speed development.

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