CHAPTER

REVIEW OF RELATED LITERATURE
CHAPTER 2

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2.1 Review of related literature and research

The review of related literature is an important aspect in any research. Knowledge acquired through generation is well displayed in books and they are arranged in libraries. Each new generation of human beings make use of accumulated knowledge, as a foundation for building up further knowledge hence the study of literature is necessary in any field of inquiry.

In the words of John W. Best (1988) the search for related literature is one of the first step in the research process. It is a valuable guide in defining the problem, recognizing its Significance, suggesting, promising data, gathering tools, appropriate study design and sources of data. Hence it is evident that review of related literature is useful for any piece of research work.

Review of Related literature is helpful to the researcher in two ways, first of all it helps the researcher to gleam the idea of others relating to a particular research question. Secondly It shows what the result of other Studies have been. The review of related literature provides ideas, theories, explanation and the like valuable information in formulating the problem and the method of research appropriate to it. Therefore a careful review of the research journals, dissertation, books and other sources of information on the related problem is one of the important step in the planning of any research study. In other words no research begins in a
vaccume. Related literature is worth while for an effective research.

The present study was undertaken to find the "The main purpose of the study was to find out the effect of plyometric and traditional training on performance of long distance athletes". At the beginning of the research study, the investigator was faced with number of issues related to this.

2.2 Previous studies

Importance of the Review

Survey of related literature serves the following purposes as,

1. To show whether the evidence already available solves the problems adequately without further investigation, and thus to avoid the risk of duplication.
2. To provide ideas, theories, explanation or hypothesis valuable in formulating the problem
3. To suggest method of research appropriate to the problem
4. To locate comparative useful in the interpretation of the result
5. To contribute the general Scholarship of the investigator.

Hence review of related literature is a valuable guide to define the problem, recognizing its significance, suggesting promising data, gathering tools and devices appropriate to the study design and also sources of data only those studies are relevant to the present study are included in the review.

Thaddens Reed Crews (1973) investigated the interaction of frequency and intensity of training and their effects
physical work capacity, cardiovascular function and body composition of adult males. 46 sedentary male members of the teaching and research faculty and staff of the University of Missouri, Columbia were pre-tested on the following variables: Physical work capacity, exercise and recovery heart rate, oxygen consumption, oxygen debt, respiratory quotient, ventilation equivalent and percent body fat. Participants were randomly assigned to one of the six training groups after an initial blocking on pre-test physical work capacity scores. At the conclusion of the pre-testing the subjects trained for seven weeks, as members of the six groups representing all possible combinations of three levels of frequency of training (five, three or one day per week), and two levels of intensity of training (exercise heart rate 150 to 120 beats per minute). All participants exercised 50 minutes per week and thus the duration of training session was dependent on the frequency of training.

Janet P. Wallace (1973) took 31 college women (aged 17 to 42) and divided them in four groups to observe the effect of four months of cardio-vascular training on the composition of body fat. Training was 3 days/week for an average 15 minutes each session, at 80% of physical work capacity. Measurement of perfect body fat, weight and girth were taken before and after months of training. Daily caloric needs and daily caloric intake were measured along with the caloric expenditure of each workout. Each group decreased in percent body fat significantly. This significant decrease was found in the group that was extremely above the optimal fat ranges. The remaining groups were within the optimal fat ranges. Weight changes did not reflect fat loss due to lean body mass.
development. Daily caloric needs were equal to daily caloric expenditure of the maintenance. All fat was therefore due to caloric expenditure of the training. Over fat individuals can reduce body fat significantly with simple cardiovascular training of walking and running. Individuals within the optimal ranges can maintain body composition with simple cardio-vascular training of walking and running. Further fat loss can be done by increasing the intensity, duration and frequency of exercise.

**Brent Swede, Burg Randy** (1975) selected 80 male college students enrolled in a conditioning class at Western Illinois University to study the effects of three different physical training treatments upon their performance and physiological changes. He divided the subjects into four groups and assigned to various treatments as follows. Treatment 1: Control group, who had no organized training during the experiment. Treatment 2: Continuous running training – i.e. the individuals assigned to this group ran two miles, three times per week at a pace determined by them. Treatment 3: Interval Running Training - these subjects ran two miles, three times per week on the basis of two miles preset time, improvement in the interval group was accomplished by increasing the length of the interval and keeping the same pace. Treatment 4: Continuous Pace Running Training - the subjects in this group ran two miles, three times per week, trying to improve the total time each day. Pre and Posttest was given to all subjects in the following areas: (a) Laboratory Test - blood pressure, Brozekkeys test of body composition, three second timed vital capacity and Astound-Rhyming test of predicated maximal oxygen uptake; (b) Field
Test- Cooper's Twelve minute run and Two mile run for time. It was concluded that all three experimental groups showed significant gains in oxygen consumption in litres and in Cooper's twelve minute at 01 level of significance, in two mile run for time as compared with control group.

Uppal Arun Kumar (1980) conducted a study to determine the effects of continuous load method and interval training on cardio-respiratory endurance and selected physiological variables. 80 untrained subjects were selected and divided them into 4 groups, i.e. 3 experimental and one control group. Out of the experimental groups, one group was given interval training, second group was allotted fartlek training, and the third group was given slow continuous running for a period of ten weeks. The load was progressively increased after every two weeks. He found that, all the 3 groups has equal training effects on maximal oxygen uptake, vital capacity, leg strength, positive breath holding time and negative breath holding time. Slow continuous and fartlek methods results in insignificantly higher improvement in cardio-respiratory endurance, when compared to interval training. Slow continuous running method and interval training were superior to fartlek in reducing resting pulse rate.

Ford HT Jr, et al. 1983) conducted the study on Effects of three combinations of plyometric and weight training programs on selected physical fitness test items. The purpose of the study was to determine the effects of prescribed training programs on 5 physical fitness test items, each of 50 high school boys participated for 10 wk. in one of three programs (wrestling, softball, and plyometrics; weight training;
and weight training and plyometrics). (a) On the sit-ups, 40-
yd. dash, vertical jump, and pull-ups, each group improved
significantly from pre- to posttest. (b) On the shuttle run, none
of the groups improved significantly from pre- to posttest. (c)
On the vertical jump, groups had a significant effect, but the
interaction was non-significant. No effects were significant.

Simpson John Steven (1987) studied to determine if
significant change would occur following participation in
selected physical education activities relative to the health
related physical fitness components: body composition, cardio-
respiratory endurance, flexibility and dynamic strength. In
addition it was determine if there were also significant
differences among the selected activities relative to the health
related fitness components and if applicable to locate the
differences. 132 students enrolled in physical education
activity courses at Tarlatan State University were the subjects.
Experimental group included those students who were
enrolled in weight training, aerobic dance and racquetball. A
control group was also analyzed in this study and consisted of
those students enrolled in archery. Pre-test procedures
involved evolutions of body composition by skin fold
measurements and cardio respiratory endurance by the 1.5
mile run. In addition flexibility was measured by the sit and
reach test and dynamic strength by the sit up test following
completion of the program activities; identical procedures were
used to collect post-test data. A correlated test was performed
to determine if there were significant differences in pre-test
and post-test scores of each item in the test battery. An
analysis of covariance (ANOVA) was calculated on the post-test
scores for the four performance variables to determine
significant difference among groups. Turkey's HSD was used to locate the differences. A difference was considered significant if it reached .05 level. Result of the study indicated that all groups experienced significant changes due to participant in the program activities. Subject involved in the weight training and aerobic dance groups experienced significant positive change in body composition, flexibility and dynamic strength. The racquetball group observed positive changes in flexibility and dynamic strength, the control group experienced significant negative changes in cardio respiratory endurance. It was concluded that improvement in body composition, flexibility and dynamic strength can occur due to participation in weight training and aerobic dance. Participation in racquetball was found to produce improvement in flexibility and dynamic strength. In addition no improvements can be expected due to participation in archery.


**Objectives:**

The purpose of the study was to find out the comparative effectiveness of specific circuit training, weight training and combination training on selected skills among basketball players.

**Conclusion**

The three experimental Training-specific circuit training method, the specific weight training method and combination
training method were found to be significantly better training methods than the control group in the enhancement of performance scores in all the variables (front shot, side shot, foul shot, under the basket shot, speed pass, jump and reach, over arm pass for accuracy, push pass and dribble) except in over arm pass or accuracy here specific circuit training method

1. The combination training method was found to be significantly superior to the other two training methods in all the above mentioned variables except in under the basket shot in which all the three training methods were found to be equally ineffective along with the control group.

2. The specific circuit training method and the specific weight training method were found to be equally effective in the improvement of performance scores in front shot, side shot, speed pass, push pass and dribble.

3. The specific circuit training method was found to be significantly superior training method than specific weight training method in the improvement of performance scores in foul shot.

4. The specific weight training method was found to be significantly superior training method than specific circuit training method in the improvement of performance scores in jump and reach test and over arm pass for accuracy test

Bhandari, Ramnami and Shaw (1995) conducted a study to investigate the effects of a long term training programme on one's performance. For the purpose of this study they selected 50 male and 25 female students of
IGIPESS, Delhi, who had undergone a six weeks training of conditioning programme (i.e. exercising with 120 ± 10 heart beats for duration of 45 minutes for five training session per week, emphasized more on endurance and flexibility with slow continuous nature) on strength improvement. The subjects were tested before and immediately after the training by employing various testing items viz. 1) vertical jump without swing,  2) vertical jump with swing,  3) broad jump,  4) sit-ups,  5) push-ups,  6) back strength,  7) Leg strength  8) right grip strength,  9) left grip strength, 10) squats, 11) Burpee jump and 12) Shuttle run. The statistical technique employed were percentage, mean percentage etc. for both the sexes. The findings revealed that, there is an improvement in strength and agility in both males and females.

**Hewett TE, Stroupe AL, Nance TA, Noyes FR.** (1996) conducted the study on Plyometric training in female athletes. Decreased impact forces and increased hamstring torques. The purpose of this study was to test the effect of a jump-training program on landing mechanics and lower extremity strength in female athletes involved in jumping sports. These parameters were compared before and after training with those of male athletes. The program was designed to decrease landing forces by teaching neuromuscular control of the lower limb during landing and to increase vertical jump height. After training, peak landing forces from a volleyball block jump decreased 22%, and knee adduction and abduction moments (medially and laterally directed torques) decreased approximately 50%. Multiple regression analysis revealed that these moments were significant predictors of peak landing forces. Female athletes demonstrated lower landing forces.
than male athletes and lower adduction and abduction moments after training. External knee extension moments (hamstring muscle-dominant) of male athletes were threefold higher than those of female athletes. Hamstring-to-quadriceps muscle peak torque ratios increased 26% on the nondominant side and 13% on the dominant side, correcting side-to-side imbalances. Hamstring muscle power increased 44% with training on the dominant side and 21% on the non-dominant. Peak torque ratios of male athletes were significantly greater than those of untrained female athletes, but similar to those of trained females. Mean vertical jump height increased approximately 10%. This training may have a significant effect on knee stabilization and prevention of serious knee injury among female athletes.

C. J. Selling (1997) have taken an expert from a study, a comparison of training methods in their effectiveness to increase the standing jump with and without a counter movement (dipping knees and swinging arms) after a set training program. After conducting my study into this comparison of training methods I found to that maximal mechanical power output training to give much better results in the standing jump test than just standard plyometric jump training. However due to the short training time and small number of testing subjects the results were not 'statistically' significant. This does raise exciting applications with regards to training of Taekwon do students in jumping for black belt gradings, and especially the National team competing in the World Champs in the destruction's division. With maximum mechanical power output training to enhance our students jumping legs we could all be really 'flying'.
Swanik KA, Lephart SM, Swanik CB, Lephart SP, Stone DA, Fu FH (2002) The effects of shoulder plyometric training on proprioception and selected muscle performance characteristics. The purpose of this study was to determine the effect of plyometric training of the shoulder internal rotators on proprioception, kinesthesia, and selected muscle performance characteristics in female swimmers. Twenty-four female division I swimmers were evaluated before and after a 6-week plyometric training program. Proprioception and kinesthesia were assessed for internal and external rotation at 0 degrees, 75 degrees, and 90% of the subject's maximum external rotation. The Biodex II was used to assess strength characteristics at 60 degrees /s, 240 degrees /s, and 450 degrees /s. Plyometric training sessions (2 times/week) involved 3 sets of 15 repetitions with a trampoline, weighted balls, and elastic tubing. A 2-way analysis of variance revealed significant improvement (P < .05) in proprioception at 0 degrees moving into external rotation, as well as 75 degrees and 90% moving into both internal and external rotation. Kinesthesia demonstrated significant improvement for all test conditions after plyometric training. Significant gains in selected muscle performance characteristics included time to peak torque (60 degrees /s and 240 degrees /s), amortization time (450 degrees /s), and torque decrement (240 degrees /s). This study suggests that plyometric activities may facilitate neural adaptations that enhance proprioception, kinesthesia, and muscle performance characteristics. Significant neuromuscular benefits may be attained if they are implemented earlier into shoulder rehabilitation programs.
Maffiuletti NA, Dugnani S, Folz M, Di Pierno E, Mauro F. (2002) conducted the study on Effect of combined electromyostimulation and plyometric training on vertical jump height. The purpose was to investigate the influence of a 4-wk combined electromyostimulation (EMS) and plyometric training program on the vertical jump performance of 10 volleyball players.

METHODS: Training sessions were carried out three times weekly. Each session consisted of three main parts: EMS of the knee extensor muscles (48 contractions), EMS of the plantar flexor muscles (30 contractions), and 50 plyometric jumps. Subjects were tested before (week 0), during (week 2), and after the training program (week 4), as well as once more after 2 wk. of normal volleyball training (week 6). Different vertical jumps were carried out, as well as maximal voluntary contraction (MVC) of the knee extensor and plantar flexor muscles. The results at week 2, MVC significantly increased (+20% knee extensors, +13% plantar flexors) as compared to baseline (< 0.05). After the 4-wk training program, different vertical jumps considered were also significantly higher compared to pertaining (< 0.001), and relative gains were comprised between 8-10% (spike-counter movement jump) and 21% (squat jump). The significant increases in maximal strength and explosive strength produced by the present training program were subsequently maintained after an additional 2 wk of Volleyball training. He found that EMS combined with plyometric training has proven useful for the improvement of vertical jump ability in volleyball players. This combined training modality produced rapid increases (approximately 2 wk) of the knee extensors and plantar flexors maximal strength. These adaptations were then
followed by an improvement in general and specific jumping ability, likely to affect performance on the court. In conclusion, when EMS resistance training is proposed for vertical jump development, specific work out (e.g., plyometric) must complement EMS sessions to obtain beneficial effects.


**Objectives:**

The purpose of the investigation was to study and compare the effects of plyometrics, circuit training and circuit breaker programmes on related physiological variables and motor components of school level tennis players.

**Conclusion**

1. Twelve weeks of planned and systematic training programme is beneficial in improving the motor components and physiological aspects of school level male Tennis players.

2. Twelve weeks of plyometric training and circuit breaker programme is effective in improving the upper body power and leg power of school level male Tennis players.

3. Both the plyometric and circuit breaker training programmes are equally effective in developing body power.

4. Plyometric circuit training and circuit breaker programmes are equally effective in developing agility, speed, muscular endurance, cardio-respiratory endurance, flexibility (back
and hip, spine), balance (static, dynamic), resting heart rate, exercise heart rate, resting respiratory rate and maximal oxygen consumption (V02max).

5. Shoulder flexibility and cardio pulmonary index are not improved by the kind of Implemented Plyometric, circuit training and circuit breaker programmes.

Spurrs R W, Murphy A J, Watsford M L (2003) conducted the study on the effect of plyometric training on distance running performance. Previous research has reported that plyometric training improves running economy (RE) and ultimately distance-running performance, although the exact mechanism by which this occurs remains unclear. This study examined whether changes in running performance resulting from plyometric training were related to alterations in lower leg musculotendinous stiffness (MTS). Seventeen male runners were pre- and post-tested for lower leg MTS, maximum isometric force, rate of force development, 5-bound distance test (5BT), counter movement jump (CMJ) height, RE, VO2max, lactate threshold (Th(la)), and 3-km time. Subjects were randomly split into an experimental (E) group which completed 6 weeks of plyometric training in conjunction with their normal running training, and a control (C) group which trained as normal. Following the training period, the E group significantly improved 3-km performance (2.7%) and RE at each of the tested velocities, while no changes in VO2max or Th(la) were recorded. CMJ height, 5BT, and MTS also increased significantly. No significant changes were observed in any measures for the C group. The results clearly demonstrated that a 6-week plyometric programme led to
improvements in 3-km running performance. It is postulated that the increase in MTS resulted in improved RE. We speculate that the improved RE led to changes in 3-km running performance, as there were no corresponding alterations in VO2max or Th(la).


Objectives

The aim of the study was whether a 6-week regimen of plyometric training would improve running economy (i.e., the oxygen cost of submaximal running).

Conclusion

1. The plyometric training added to running training improves running economy must be restricted to the conditions of this study. For one thing, our subjects were not highly trained runners. It may be more difficult to improve economy in highly trained runners, who already are very economical as a rule.

2. The primary rationale in using less trained runners was the hope that economy would be more easily affected in such subjects. We also used a relatively short-term (6 weeks) and moderate plyometric training program.

3. Our study sheds no light on the possible effects of longer or more intense training programs. With these qualifications, we have concluded that relatively moderate and short-term plyometric training improves running economy in regular, but not highly trained runners.
4. The improvement in economy after the plyometric training was small (2–3%), but small differences in economy can be important in competitive distance running.

5. Also, the training program was not intense. It is reasonable to think that greater improvements in economy may be realized with more intense or prolonged training, although this requires verification in future studies.

6. The improved economy occurred independent of a change in VO2' max. This is important because VO2 max typically reaches a peak value for an athlete relatively quickly with training. After this, improvements in endurance performance that depend on physiological adaptations require other changes, such as changes in economy. Based on our findings, one way to improve economy is by way of plyometric training.

Caputo F, Denadai B S., (2004) conducted a study on effects of aerobic endurance training status and specificity on oxygen uptake kinetics during maximal exercise. The main purpose of this study was to analyse the effects of exercise mode, training status and specificity in the oxygen uptake (VO2 max) kinetics during maximal exercise performed in treadmill running and cycle ergometer. Seven runners (R), nine cyclists (C), nine tri athletes (T) and eleven untrained subjects (U), performed the following tests on different days on a motorized treadmill and on a cycle ergometer. The U group showed the lowest values for VO2 max, regardless of exercise mode. Differences in tau VO2 (seconds) were found only for the U group in relation to the trained groups [R=31.6 (10.5) and 40.9 (13.6); C=28.5 (5.8) and 32.7 (5.7); t=32.5 (5.6) and 40.7 (7.5);]
U = 52.7 (8.5) and 62.2 (15.3) for the treadmill and cycle ergometer, respectively; no effects of exercise mode were found in any of the groups. It is concluded that VO$_2$max during the exercise performed at VO$_2$max is dependent on the training status, but not dependent on the exercise mode and specificity of training. Moreover, the transfer of the training effects on tau VO$_2$max between both exercise modes may be higher compared with VO$_2$max.


Objectives

The aim of this study was to examine the effects of a specific plyometric training programme, when combined with the conventional rugby training, on selected physical capacities of rugby players.

Conclusion

From the analysis of the results of this study it was clear that:

1. Even a relatively short programme of plyometric training produced positive changes in the abilities of rugby players.

2. Plyometrics produce positive results in the physical capabilities of those using this training (these physical capabilities were a compound aggregate of: explosive power [demonstrated by the triple jump, depth jump and vertical jump], speed [ten-meter speed test] and agility [agility runs]).
3. Equally, the plyometric programme also produced positive and beneficial anthropometric changes (demonstrated by body composition and girth measurements) for rugby players.

4. This short plyometric programme also improved cardiovascular fitness (as tested by the three-minute step test) and lower body muscle endurance (as tested by the sit-up test) though upper body muscle groups (as tested by the push-up test), did not.


Objectives

The aim of this study was to evaluate the effects of plyometric training on muscle-activation strategies and performance of the lower extremity during jumping exercises.

Conclusion

From the analysis of the results of this study it was clear that:

1. Plyometric training induced beneficial neuromuscular adaptations in the hip adductor muscles that may assist with knee stability.

2. Adductor muscle preactivation and adductor and abductor coactivation both increased after plyometric training.
3. The neuromuscular adaptations, combined with previous kinematic and kinetic data, strongly support the use of plyometric training to enhance dynamic restraint and functional stability at the knee joint.

4. The observations also suggest that more emphasis should be placed on hip-muscle performance and coordination in the training regimen of female athletes to minimize the risk of knee injuries.

Rubenstein (2004) compared the effects of a four-week, general resistance training programme (G) to a four-week combined plyometrics and general resistance training programme (GP) on shot speed on - goal (SS) in Division I Women's Soccer players. Eight members of the Manhattan College Women's Soccer Programme (19-22 yrs.) were randomly assigned to either G (n=4) or GP (n=4). Prior to and subsequent to training, each subject was tested for SS using radar (Sports Radar 3500). Briefly, subjects were asked to kick the ball (size 5, inflated to 6-1.01 atmospheres) maximally to a target 18ft away. Only trials that fell within 10-degree angle of trajectory relative to the device (visual inspection) were accepted as supported by the manufactures manual. All subjects took a running start (3-4 steps). Three trials were averaged for each subject and the means were compared using dependent ‘t’-tests. Neither group improved significantly (p>.05), however GP showed trends (p=.06) favouring increased SS (47.4 ± 2.0 mph PRE vs. 48.0 ± 2.0 mph POST) while G decreased slightly (50.2 ± 4.9 mph PRE vs. 49.8 ± 2.8 mph POST).
Toumi H, Best et al, (2004). Examined a study on the Effects of eccentric phase velocity of plyometric training on the vertical jump. The aim of the study was to compare the effects of plyometric training performed with rapid (or) slow stretch contractions on jump performance and muscle properties were compared. Thirty males between the ages of 19 and 22 volunteered for the 8-week experiment. Subjects were divided into the following three groups: training groups (1)(TG1) training group2 (TG2) and control group (CG, n=6). Each of the 2 experimental groups underwent a unique training regimen. For the first group (TG1, n=12) from a standing position, the subject flexed his knees to a 90 degrees angle with velocity standardized and controlled at 0.4m/s and immediately performed a leg extension as quickly as possible. For the second group (TG2, n=12): from a standing position, the subject flexed his knees to a 90 degrees angles with velocity standardized at 0.2m/s and then performed a leg extension as quickly as possible. Each exercise consisted of six sets of ten repetitions with barbell on the shoulders at 70% of the maximal isometric force (IRM). The 70% load was modified at two weak intervals by evaluating a new 1RM. Exercises were performed four times a week over the eight week period the third group(CG)(n=6)served as control group. Maximal isometric force(MVC), maximal concentric force, squat jump(SJ)and counter movement exercise (CMJ) were performed before and after the training program. Subjects were filmed (100HZ) and each jump was divided into three phases: Eccentric phases (ECG), transition phases (TR) and concentric phases (CON), surface EMG was used to determine the changes in the electromyography (EMG) activity before and
after the training program. There was an increase in leg extension force, velocity and electrical activity for SJ and CMJ for the two training groups (P<0.05). However, TG1 showed a significant advantage in CMJ performance as well as a significant decrease in TR compared to the TG2 (P<0.05). The results of this study show that when plyometric training performed with rapid stretch contraction, the CMJ jump height increase and the TR decrease.

Herrero J.A., et al, (2006). A study on electromyostimulation and plyometric training effects on jumping and sprint time. 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 extends or muscles on 20 M sprint time (ST), jumping ability (squat jump) (SJ) and countermovement hump (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 obverted −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 in both humps 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 < 0.05) in CSA was observed after training in EG (9.0%) and in EPG (7.1%). EMS combined with plyometric training increased the humping height and sprint run in physically active men. In addition, DMS 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 in any improvement in jumping explosive strength development or even interfered in sprint run.

Myer GD., et al, (2006). Determined the effects of plyometric vs dynamic stabilization and balance training on power, balance, and landing force in female athletes. Neuromuscular training protocols that include both plyometrics and dynamic balance exercises can significantly improve biomechanics and neuromuscular performance and reduce anterior cruciate ligament injury risk in female athletes. The purpose of this study was to compare the effects of plyometrics (PLYO) versus dynamic stabilization and balance training (BAL) on power, balance, strength, and landing force in female athletes. Either PLYO or BAL were included as a component of a dynamic neuromuscular training regimen that reduced measures related to ACL injury and increased measures of performance. Nineteen high school female athletes participated in training 3 times a week for 7 weeks. The PLYO (n = 8) group did not receive any dynamic balance exercises and the BAL (n = 11) group did not receive any maximum effort jumps during training. Pre training vs. post training measures of impact force and standard deviation of centre of pressure (COP) were recorded during a single leg hop and hold. Subjects were also tested for training effects in
strength (isokinetic and isoinertial) and power (vertical jump). The percent change from pre-test to post-test in vertical ground reaction force was significantly different between the BAL and PLYO groups on the dominant side (p < 0.05). Both groups decreased their standard deviation of centre of pressure (COP) during hop landings in the medial/lateral direction on their dominant side, which equalized pretested side to side differences. Both groups increased hamstrings strength and vertical jump. The results of this study suggest that both PLYO and BAL training are effective at increasing measures of neuromuscular power and control. A combination of PLYO and BAL training may further maximize the effectiveness of preseason training for female athletes.

Castagna C., et al., (2007). Conducted a study on Relation between maximal aerobic power and the ability to repeat sprints in young basketball players. The aim of this study was to examine the effects of maximal aerobic power (VO2 max peak) level on the ability to repeat sprints (calculated as performance decrement and total sprinting time) in young basketball players. Subjects were 18 junior, well-trained basketball players (age, 16.8 +/- 1.2 years; height, 181.3 +/- 5.7 cm; body mass, 73 +/- 10 kg; VO2 max peak, 59.6 +/- 6.9 ml x kg (-1) x min (-1)). Match analysis and time - motion analysis of competitive basketball games was used to devise a basketball - specific repeated - sprint ability protocol consisting of ten 15-m shuttle run sprints with 30 s of passive recovery. Pre, post, and post plus 3-minute blood lactate concentrations were 2.5 +/- 0.7, 13.6 +/- 3.1 and 14.2 +/- 3.5 mmol x L (-1), respectively. The mean fatigue index (FI) value was 3.4 +/- 2.3% (range, 1.19.1%). No significant correlations
were found between VO2max peak and either FI or total sprint time. A negative correlation ($r=-0.75$, $p=0.01$) was found between first-sprint time and FI. The results of this study showed that VO2 max peak is not a predictor of repeated sprint ability in young basketball players. The high blood lactate concentrations found at the end of the repeated-sprint ability protocol suggests its use for building lactate tolerance in conditioned basketball players.

**Luebbers PE., et al, (2007)** have demonstrated briefly kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. Jumping is an important performance component of many sporting activities. A number of training modalities have been used to enhance jumping performance including plyometrics. The positive effects of plyometric training on jumping performance are a function of the stretch-shortening cycle phenomenon. However, there has been little research on the effects of the surface on jumping performance. This study examined the effects of performing 2 different plyometric exercises, depth jump (DJ) and counter movement jump (CMJ), on noncompliant (ground) and compliant (mini-trampoline) surfaces. Male participants ($N = 20$; age $= 21.8\pm0.8$ years; height $= 184.6 \pm 7.6$ cm; mass $= 83.6 \pm 8.2$ kg) randomly performed 10 CMJ and 10 DJ on compliant and noncompliant surfaces. Kinematic data were determined via 2-dimensional high-speed video. There were significant ($p < 0.05$) differences in DJ and CMJ joint and segment range of movement for ankle, knee, hip and trunk, indicating less crouch when the participants performed plyometric exercises on the compliant surface.
Markovic G, Jukic I, Milanovic D, Metikos D. (2007) conducted the study on Effects of sprint and plyometric training on muscle function and athletic performance. 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 assigned randomly to 1 of 3 groups: sprint group (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 (3.2 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 (10%; 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 (4.3%; 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 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.

**Markovic G., (2007)** Conducted on Does plyometric training improve vertical jump height? A meta-analytical review. The aim of this study was to determine the precise effect of plyometric training (PT) on vertical jump height in healthy individuals. Meta-analyses of randomized and non-randomized controlled trials that evaluated the effect of PT on four typical vertical jump height tests were carried out: squat jump (SJ); countermovement jump (CMJ); countermovement jump with the arm swing (CMJA); and drop jump (DJ). Studies were identified by computerized and manual searches of the literature. Data on changes in jump height for the plyometric and control groups were extracted and statistically pooled in a meta-analysis, separately for each type of jump. A total of 26 studies yielding 13 data points for SJ, 19 data points for CMJ, 14 data points for CMJA and 7 data points for DJ met the initial inclusion criteria. The pooled estimate of the effect of PT on vertical jump height was 4.7% (95% CI 1.8 to 7.6%), 8.7% (95% CI 7.0 to 10.4%), 7.5% (95% CI 4.2 to 10.8%) and 4.7% (95% CI 0.8 to 8.6%) for the SJ, CMJ, CMJA and DJ, respectively. When expressed in standardized units (i.e. effect sizes), the effect of PT on vertical jump height was 0.44 (95% CI 0.15 to 0.72), 0.88 (95% CI 0.64 to 1.11), 0.74 (95% CI 0.47 to 1.02) and 0.62 (95% CI 0.18 to 1.05) for the SJ, CMJ, CMJA and DJ, respectively. PT provides a statistically significant and practically relevant improvement in vertical jump height with the mean effect ranging from 4.7% (SJ and DJ), over 7.5% (CMJA) to 8.7% (CMJ). These results justify the application of
PT for the purpose of development of vertical jump performance in healthy individuals.

Kotzamanidis C. (2007) conducted the study on Effect of plyometric training on running performance and vertical jumping in prepubertal boys. 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 distances (0-10 m, 10-20 m, 20-30 m, and 0-30 m), were selected as testing variables 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.

Ratamess NA., et al, (2007) conducted a study on effects of ten weeks of resistance and combined plyometric/sprint training with the Meridian Elite athletic
shoe on muscular performance in women. The purpose of this investigation was to examine the combined effects of resistance and sprint/plyometric training with or without the Meridian Elite athletic shoe on muscular performance in women. Fourteen resistance-trained women were randomly assigned to one of 2 training groups: (a) an athletic shoe ($N = 6$) (AS) group or (b) the Meridian Elyte ($N = 8$) (MS) group. Training was performed for 10 weeks and consisted of resistance training for 2 days per week and 2 days per week of sprint/plyometric training. Linear periodized resistance training consisted of 5 exercises per workout (4 lower body, 1 upper body) for 3 sets of 3-12 repetition maximum (RM). Sprint/plyometric training consisted of 5-7 exercises per workout (4-5 plyometric exercises, 40-yd and 60-yd sprints) for 3-6 sets with gradually increasing volume (8 weeks) followed by a 2-week taper phase. Assessments for 1RM squat and bench press, vertical jump, broad jump, sprint speed, and body composition were performed before and following the 10-week training period. Significant increases were observed in both AS and MS groups in 1RM squat (12.0 vs. 14.6 kg), bench press (6.8 vs. 7.4 kg), vertical jump height (3.3 vs. 2.3 cm), and broad jump (17.8 vs. 15.2 cm). Similar decreases in peak 20-, 40-, and 60-m sprint times were observed in both groups (20 m: 0.14 vs. 0.11 seconds; 40 m: 0.29 vs. 0.34 seconds; 60 m: 0.45 vs. 0.46 seconds in AS and MS groups, respectively). However, when sprint endurance (the difference between the fastest and slowest sprint trials) was analysed, there was a significantly greater improvement at 60 m in the MS group. These results indicated that similar improvements in peak sprint speed and jumping ability were observed
following 10 weeks of training with either shoe. However, high-intensity sprint endurance at 60 m increased to a greater extent during training with the Meridian Elyte athletic shoe.

Stemm JD., et al, (2007) investigated the difference of land- and aquatic-based plyometric training on vertical jump performance. Plyometric training is a popular method by which athletes may increase power and explosiveness. However, plyometric training is considered a highly intense and potentially damaging activity particularly if practiced by the novice individual or if overdone. The purpose of this study was to compare vertical jump performance after land- and aquatic- based plyometric training. A convenience sample of 21 active, college-age (24 +/- 2.5 years) men were randomly assigned to 1 of 3 groups: group I, aquatic; group II, land; and group III, control. Training for the AQ and LN groups consisted of a 10- minute warm-up followed by 3 sets of 15 squat jumps, side hops, and knee-tuck jumps separated by 1-minute rests. The aquatic group performed the exercises in knee-level water adjusted to parallel the axis of the knee joint (+1 in.). The land group performed identical plyometric exercises on land. The control group engaged in no training. Participants trained twice a week for 6 weeks, and all training sessions were monitored. Pre- and post-test data were collected on maximum vertical jump height. A 2x3 analysis of variance with repeated measures was used to compare vertical jump height among the 3 groups. Results suggested that the aquatic- and land-based groups significantly (p < 0.05) outperformed the control group in the vertical jump. No significant difference was found in vertical jump performance between the aquatic- and land-
based groups. It was concluded that aquatic training resulted in similar training effects as land-based training, with a possible reduction in stress due to the reduction of impact afforded by the buoyancy and resistance of the water upon landing.

Castagna C., et al, (2008) conducted a study on effect of recovery mode on repeated sprint ability in young basketball players. The aim of this study was to examine the effect of recovery mode on repeated sprint ability in young basketball players. Sixteen basketball players (age, 16.8 +/- 1.2 years; height, 181.3 +/- 5.7 cm; body mass, 73 +/- 10 kg; vo2max 59.5 +/- 7.9 ml x kg(-1) x min(-1)) performed in random order over 2 separate occasions 2 repeated sprint ability protocols consisting of 10x30-m shuttle run sprints with 30 seconds of passive or active (running at 50% of maximal aerobic speed) recovery. Results showed that fatigue index (FI) during the active protocol was significantly greater than in the passive condition (5.05 +/- 2.4, and 3.39 +/- 2.3, respectively, p<0.001). No significant association was found between VO2 peak and FI and Sprint total time (TT) in either repeated sprint protocols. Blood lactate concentration at 3 minutes post exercise was not significantly different between the 2 recovery conditions. The results of this study show that during repeated sprinting, passive recovery enabled better performance, reducing fatigue. Consequently, the use of passive recovery is advisable during competition in order to limit fatigue as a consequence of repeated high intensity exercise.
Chtara M., et al, (2008) conducted a study on the effect of concurrent endurance and circuit resistance training sequence on muscular strength and power development. The purpose of this study was to examine the influence of the sequence order of high intensity endurance training and circuit training on changes in muscular strength and anaerobic power. Forty eight physical education students (ages, 21.4 +/- 1.3 years) were assigned to one of five groups: no training controls (C, n = 9), endurance training (E, n = 10), circuit training (S, n = 9), endurance before circuit training in the same session, (E+S, n = 10), and circuit before endurance training in the same session (S+E, n = 10). Subjects performed 2 sessions per week for 12 weeks. Resistance type circuit training targeted strength endurance (Weeks 1-6) and explosive strength and power (weeks 7-12). Endurance training sessions included a 5 repetition run at a velocity associated with VO2 max (VO2 max) for duration equal to 50% of the time to exhaustion at VO2 max; recovery was for an equal period at 60% of VO2 max. Maximal strength in the half squat, strength endurance in the 1-leg half squat and hip extension, and explosive strength and power in a 5 jumps test and countermovement jump were measured pre-test and post-testing. No significant differences were shown following training between the S+E and E+S groups for all exercise tests. However, both S+E and E+S groups improved less than the S group in 1 repetition maximum (p < 0.01), right and left 1-leg half squat (0 < 0.02), 5 jump test (p < 0.01), peak jumping force (p < 0.05), peak jumping power (p < 0.02), and peak jumping height (p < 0.05). The intra-session sequence did not influence the adaptive response of muscular strength and explosive strength and power. Circuit
training alone induced strength and power improvements that were significantly greater than when resistance and endurance training were combined, irrespective of the intra session sequencing.

De Villarreal ES, et al, (2008) Conducted a study on Low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency. The purpose of this study was to examine the effect of 3 different plyometric training frequencies (e.g., 1 day per week, 2 days per week, 4 days per week) associated with 3 different plyometric training volumes on maximal strength, vertical jump performance, and sprinting ability. Forty-two students were randomly assigned to 1 of 4 groups: control (n = 10, 7 sessions of drop jump (DJ) training, 1 day per week, 420 DJs), 14 sessions of DJ training (n = 12, 2 days per week, 840 DJs), and 28 sessions of DJ training (n = 9, 4 days per week, 1680 DJs). The training protocols included DJ from 3 different heights 20, 40, and 60 cm. Maximal strength (1 repetition maximum [1RM] and maximal isometric strength), vertical height in countermovement jumps and DJs, and 20-m sprint time tests were carried out before and after 7 weeks of plyometric training. No significant difference was observed among the groups in pre-training in any of the variables tested. No significant changes were observed in the control group in any of the variables tested at any point. Short-term plyometric training using moderate training frequency and volume of jumps (2 days per week, 840 jumps) produces similar enhancements in jumping performance, but greater training efficiency (approximately 12% and 0.014% per jump) compared with high jumping (4 days per week, 1680
jumps) training frequency (approximately 18% and 0.011% per jump). In addition, similar enhancements in 20-m-sprint time, jumping contact times and maximal strength were observed in both a moderate and a low number of training sessions per week compared with high training frequencies, despite the fact that the average number of jumps accomplished in 7S (420 jumps) and 14S (840 jumps) was 25 and 50% of that performed in 28S (1680 jumps). These observations may have considerable practical relevance for the optimal design of plyometric training programs for athletes, given that a moderate volume is more efficient than a higher plyometric training volume.

Impellizzeri FM, et al., (2008) conducted a study on Effect of plyometric training on sand versus grass on muscle soreness and jumping and sprinting ability in soccer players. The lower impact on the musculoskeletal system induced by plyometric exercise 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 versus a grass surface on muscle soreness, vertical jump height and sprinting ability. Parallel two-group, randomized, longitudinal (pre-test- 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. 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). 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.

Marques MC, et al., (2008) Conducted a study on changes in strength and power performance in elite senior female professional volleyball players during the in-season: a case study. It is often recommended that in-season training programs aim to maintain muscular strength and power developed during the off-season. However, improvements in performance may be possible with a well-designed training regimen. The purpose of this case report is to describe the changes in physical performance after an in-season training regimen in professional female volleyball players in order to determine whether muscular strength and power might be improved. Apart from normal practice sessions, 10 elite female volleyball players completed 2 training sessions per week, which included both resistance training and plyometric exercises. Over the 12-week season, the athletes performed 3-4 sets of 3-8 repetitions for resistance and plyometric exercises during each training
session. All sessions were supervised by one of the investigators as well as by the team head coach. Muscular strength and power were assessed before and after the 12-week training program using 4 repetition maximum bench press and parallel squat tests, an overhead medicine ball throw (BTd), as well as unloaded and loaded countermovement jumps (CMJs). Strength improved by 15% and 11.5% in the bench press and parallel squat, respectively (p < 0.0001). Distance in the BTd improved by 11.8% (p < 0.0001), whereas unloaded and loaded CMJ height increased between 3.8 and 11.2%. The current findings suggest that elite female volleyball players can improve strength and power during the competition season by implementing a well-designed training program that includes both resistance and plyometric exercises.


Objectives:

The present study was designed to find out the Effect of Isolated and Combined Weight and Plyometric Training and Detraining on selected Strength and Speed Parameters such as Arm Strength, Leg Strength, Explosive Strength, Strength Endurance, Speed, Stride Length, Stride Frequency and Speed Endurance of College men.

Conclusion
1. All the experimental groups namely weight training, plyometric training and combined weight and plyometric training groups have achieved significant improvement on Arm Strength, Leg Strength, Explosive Strength, Strength Endurance, Speed, Stride length, Stride Frequency and Speed Endurance.

2. Significant differences were found among weight training, plyometric training, combined weight and plyometric training groups towards improving the selected criterion variables such as Arm Strength, Leg Strength, Explosive Strength, Strength Endurance, Speed, Stride length, Stride Frequency and Speed Endurance.

3. It was also concluded that, combined weight and plyometric training were found to be better than weight training and plyometric training towards improving Arm Strength, Leg Strength, Explosive Strength, Strength Endurance, Speed, Stride length, Stride Frequency and Speed Endurance.

4. There was no significant reduction in the performance of selected strength and speed parameters during the first and second cessation of detraining period.

5. Significant reduction in the performance of selected strength and speed parameters were found during the third and fourth cessation of detraining period.
Perez-Gomez J, et al, (2008) conducted a study on effects of weight lifting training combined with plyometric exercises on physical fitness, body composition, and knee extension velocity during kicking in football. The effects of a training program consisting of weight lifting combined with plyometric exercises on kicking performance, myosin heavy-chain composition (vastus lateralis), physical fitness, and body composition (using dual-energy X-ray absorptiometry (DXA)) was examined in 37 male physical education students divided randomly into a training group (TG: 16 subjects) and a control group (CG: 21 subjects). The TG followed 6 weeks of combined weight lifting and plyometric exercises. In all subjects, tests were performed to measure their maximal angular speed of the knee during in-step kicks on a stationary ball. Additional tests for muscle power (vertical jump), running speed (30 m running test), anaerobic capacity (Wingate and 300 m running tests), and aerobic power (20 m shuttle run tests) were also performed. Training resulted in muscle hypertrophy (+4.3%), increased peak angular velocity of the knee during kicking (+13.6%), increased percentage of myosin heavy-chain (MHC) type IIa (+8.4%), increased 1 repetition maximum (1 RM) of inclined leg press (ILP) (+61.4%), leg extension (LE) (+20.2%), leg curl (+15.9%), and half squat (HQ) (+45.1%), and enhanced performance in vertical jump (all p < or = 0.05). In contrast, MHC type I was reduced (-5.2%, p < or = 0.05) after training. In the control group, these variables remained unchanged. In conclusion, 6 weeks of strength training combining weight lifting and plyometric exercises results in significant improvement of kicking
performance, as well as other physical capacities related to success in football (soccer).

Ronnestad BR., et al, (2008) compared the effects of combined strength and plyometric training with strength training alone on power-related measurements in professional soccer players. Subjects in the intervention team were randomly divided into 2 groups. Group ST (n = 6) performed heavy strength training twice a week for 7 weeks in addition to 6 to 8 soccer sessions a week. Group ST+P (n = 8) performed a plyometric training program in addition to the same training as the ST group. The control group (n = 7) performed 6 to 8 soccer sessions a week. Pre-tests and post tests were 1 repetition maximum (1RM) half squat, countermovement jump (CMJ), squat jump (SJ), 4-bounce test (4BT), peak power in half squat with 20 kg, 35 kg, and 50 kg (PP20, PP35, and PP50, respectively), sprint acceleration, peak sprint velocity, and total time on 40-m sprint. There were no significant differences between the ST+P group and ST group. Thus, the groups were pooled into 1 intervention group. The intervention group significantly improved in all measurements except CMJ, while the control group showed significant improvements only in PP20. There was a significant difference in relative improvement between the intervention group and control group in 1RM half squat, 4BT, and SJ. However, a significant difference between groups was not observed in PP20, PP35, sprint acceleration, peak sprinting velocity, and total time on 40-m sprint. The results suggest that there are no significant performance enhancing effects of combining strength and plyometric training in professional soccer players concurrently performing 6 to 8 soccer sessions.
a week compared to strength training alone. However, heavy strength training leads to significant gains in strength and power-related measurements in professional soccer players.

Saez, DeVillarreal E., et al, (2008) conducted a study on effect of plyometric training on chair-rise, jumping and sprinting performance in three age groups of women. The main purpose of this study was to investigate the influence of 8-wk periodized plyometric training (PT) on chair-rise, jumping and sprinting performance in three groups of women of different age (40-50; 50-60; 60-70 years). This study involved a group of 55 women between the ages of 40 and 70 with no PT experience participating in a gymnastic program and recreational activity that did not involve jumping and who had participated since five years. All tests to determine the values of strength endurance, vertical jumping performance (VJP) and velocity were carried out before (PRE), after (POST) and following 8 weeks of rest (DETRAINING) of the 8 weeks of PT. The performance tests were completed in 3 days. The primary finding of this investigation indicates that low impact PT using moderate volume of jumps produced similar enhancements in the three age groups of women in jumping and chair-rise performance (30 CST) (ranging 15-24 %). There were no enhancements in 10 m-sprint time in any of the age groups. In addition, 8 weeks of detraining following an 8 week PT program resulted in similar decreases in chair-rise and jumping performance in all training groups, whereas no further changes were observed in 10-m sprint time. The low impact PT proposed appears to be an optimal stimulus for improving VJP and 30 CST during short-term training periods in untrained middle-aged and elderly women.
Saunders et al, (2008) Compared short-term plyometric training improves running economy highly trained middle and long distance runners. Fifteen highly trained distance runners vo2 max (71.1+/-6.0ml min ((-1) kg (-1), mean +/- SD) were randomly assigned to a plyometric training (ply; n=7) or control (con;n=8) groups . In addition to their normal training, the ply group undertook 3 x30 minutes ply sessions per week for 9 weeks , running economy (RE) was assessed during 3 x4 minutes treadmill runs (14,16 and 18ikm .h(-1), followed by an incremental test to measure vo2 max . Muscle power characteristics were assessed on a portable unidirectional ground reaction force plate, compared with con, ply improved RE at 18km .h (1) (4.1% ,p=0.002), but not at 14 ore 16 km.h(-
1) .this was accompanied by trends for increased average power during a 5 jump plyometric test ( 15%) p=0.11) , a shorter time to reach maximal dynamic strength during a strength ; During strength quality assessment test (14%,p=0.009) and a lower vo2 max speed slope (14% ,p=0.12 ) after 9 weeks of ply. There were no significant differences in cardio respiratory measures or vo2 max as a result of ply. In a group of highly- trained distance runners, 9 weeks of ply improved RE, with likely mechanisms residing in the muscle, or alternatively by improving running mechanics.

Solanikidis K, et al, (2008) the purpose of the study was to determine the effectives of plyometric, tennis drills and combined on reaction lateral and linear speed, power and strength in novice tennis player's Reaction time, first-step quickness, lateral (side steps), and forward speed over short distances are important parameters for tennis performance. The aims of this study were: (i) to diagnose the presence of
laterality in tennis lateral movements and (ii) to compare the effects of plyometric training (PT), tennis-specific drills training (TDT), and combined training (CT) on performance in tennis-specific movements and power/strength of lower limbs. Sixty-four novice tennis players (21.1 +/- 1.3 years) were equally (n = 16) assigned to a control (C), PT, TDT, or CT. Training was performed 3 times/week for 9 weeks. Testing was conducted before and after training for the evaluation of reaction time (single lateral step), 4- m lateral and forward sprints, 12-m forward sprints with and without turn, reactive ability, power, and strength. There was a significant difference in lateral speed (side-steps) between the 2 sides (P < 0.05). PT, TDT, or CT improved the 4m lateral and forward sprints (P < 0.05). PT and CT improved also the reaction time of the "slow" side (P < 0.05), whereas TDT and CT improved the 12-m sprint performances with and without turn (P < 0.05). Power and strength improved in most tests after PT and CT. Lateral and forward sprints were correlated (r = -0.50 to -0.75; P < 0.05) with power/strength. In conclusion, PT improved fitness characteristics that rely more on reactive strength and powerful push-off of legs such as, lateral reaction time, 4-m lateral and forward sprints, drop jump and maximal force. TDT improved all 4-m and 12-m sprint performances, whereas CT appeared to incorporate the advantage of both programs and improved most tests items. Tennis coaches should be aware that each training regimen may induce more favourable changes to different aspects of fitness, response to strength training is, in part, modulated by the muscle phenotype (MHC isoform composition) despite the increase in osteocalcin, and fat mass was not reduced.
**Vescovi JD., et al, (2008)** compared the effort of a plyometric program on vertical landing force and jumping performance in college women. Subjects were assigned to one of the three groups; an experimental group I (E.G-I), experimental group -II (E.G.-II) and control group (CG). The EG-I, EG-II groups participated in two packages of plyometric training in 50 minutes session for 6 weeks and 60 minute. No specific training is given for control group. The E.G -I included a warm ups, 30-35 min, and a 5 -min cool down. The E.G.- I I included a 5-7 min warm –up 35- 40 min and a 5-7 min cool down’ comparisons were, made using Mann- Whitney u test. Results showed in the intervention group (-222.8 +/- 610.9 N), but was not statistically different (P= 0.122); compared to the change observed in the control group (54.6+/- 257.6N) there was no difference in the absolute change values between groups for counter movement jump height (1.0+/ -2.8 cm vs. -0.2 +/-1.5 cm, p=0.696). It was concluded, although not statistically significant, the mean absolute reduction in vertical ground reaction force in the training group is clinically meaning full. Eight of the 10 women in the training group reduced vertical ground reaction force by 17.18 -%: however, improvements in jumping performance were not absorbed. This indicates that programs aimed at enhancing performance must be designed differently from those aimed at reducing landing forces in recreationally athletic women.

**Villarreal et al, (2008)** Study on compared the low and moderate plyometric training frequency produces greater jumping and sprinting gains compared with high frequency, forty two students were randomly assigned to 1 of 4 groups: control14 sessions of DJ training and 28 sessions of
DJ training. The training protocols included DJ from 3 different heights 20, 40 and 60cm. Maximal strength, vertical height in counter movements jumps and DJ's and 20m sprint timers tests were carried out before and after 7 weeks of plyometric training. No significant difference was observed among the groups in pre training in any of the variables tested. No significant changes were observed in the control groups in any of the variables tested at any point. Short-term plyometric training using moderate training frequency and volume of jumps produce similar enhancements in jumping performance, but greater training efficiency compared with high jumping training frequency. In addition, similar enhancements in jumping performance, but greater training frequency. In addition, similar enhancements 20 m sprint time, jumping contact times and maximal strength were observed in both a moderate and low number of training sessions per week compared with high training frequencies, despite the fact that the average number of jumps accomplished in 7s was 25 and 50% of the that performed in 28s. These observations may have considerable practical relevance for the optimal design of plyometric training program for athletes, given that a moderate volume is more efficient than a higher plyometric training volume.

Guadalupe-grau A et al, (2009) conducted a study on the strength training combined with plyometric jumps in adults: sex differences in fat bone axis adaptations. Lepton and osteocalcin play a role in the regulation of the fat bone axis and may be altered by exercise. To determine whether osteocalcin reduces fat mass in humans fed ad libium and if there is a sex dimorphism in the serum osteocalcin and lepton
responses to strength training, we studied 43 male (age 23.9 ± 2.4 yr., mean +/- SD) and 23 female physical education students (age 23.2 ± 2.7 yr.). Subjects were randomly assigned to two groups: training (TG) and control (CG). TG followed a strength combined with plyometric jumps training program during 9 weeks, whereas the CG did not train. Physical fitness, body composition (Dual-energy X-ray absorptiometry). In the whole group of subjects (pre-training), the serum concentration of osteocalcin was positively correlated ($r=0.29-0.42$, $p < 0.05$) with whole body and regional bone mineral content, lean mass, dynamic strength, and serum free testosterone concentration ($r=0.32$). However, osteocalcin was negatively correlated with leptin concentration ($r=0.37$), fat mass ($r=-0.31$), and the percent body fat ($r=-0.44$). Both sexes experienced similar relative improvements in performance, lean mass (+4-5%), and whole body (+0.78%) and lumbar spine bone mineral content (+1.2-2%), with training. Serum osteocalcin concentration was increased after training by 45 and 27% in men and women, respectively ($p < 0.05$). Fat mass was not altered by training. Vastus laterals type II MHC compositional at the start of the training program predicted 25% of the osteocalcin increase after training. Serum leptin concentration was reduced either training in women. In summer, while the relative effecter’s strength training plus plyometric jumps in performance. Muscle hypertrophy, and osteogenesis are similar in men and women, serum leptin concentration is reduced only in women. The osteocalcin response to strength trainings is in reduced only in women. The osteocalcin response to strength training is, in part, modulated by the
muscle phenotype (MHC isoform composition) despite the increase in osteocalcin, fat mass was not reduced.

**Drinkwater E J, et al, (2009)** conducted a study on **Effect of an acute bout of plyometric exercise on neuromuscular fatigue and recovery in recreational athletes.** Although plyometric training is widely used by sports coaches as a method of improving explosive power in athletes, many prescribe volumes in excess of the National Strength and Conditioning Association recommendations. The purpose of this study was to assess voluntary and evoked muscle characteristics to assess the neuromuscular impact of a high-volume about of plyometric exercise that was non-exhaustive. Ten athletes who did not have plyometric training experience were in their competitive season for club-level sport volunteered for the study. After at least 2 days without high-intensity activity, subjects were assessed on maximal twitch torque, time to peak torque, rate of twitch torque development, twitch half-relaxation time, rate of twitch relaxation, and voluntary activation by the interpolated twitch technique before, immediately after, and 2 hours after a high-volume plyometric training program (212 ground contacts). Data were analysed by repeated-measures analysis of variance and described as mean +/- SD and Cohen d. Statistically significant decrements appeared immediately after the training protocol in the total torque generated by maximal voluntary contractions \( p < 0.05, d = -0.51 \) and twitch \( p < 0.01, d = -0.92 \), rate of twitch torque development \( p < 0.01, d = -0.77 \), and rate of relaxation \( p < 0.01, d = -0.73 \). However, we did not observe any differences that remained statistically different after 2 hours. There were no significant differences observed at
any time point in time to peak twitch, half-relaxation time, or voluntary activation. We conclude that high-volume plyometric training results primarily in peripheral fatigue that substantially impairs force and rate of force development. We recommend that coaches carefully monitor the volume of plyometric training sessions to avoid neuromuscular impairments that can result in sub optimal training.

Johanna R. Olson (2009), A Thesis, VO_{2peak} and Running Economy in Female Collegiate Soccer Players across a Competitive Season submitted to Oregon State University.

Objectives

To examine RE and VO_{2max} values across a season in female NCAA Division I soccer athletes

Conclusion

1. The results of this study, which found no change from pre-season to post-season testing in VO_{2peak} and RE, may have been influenced by many factors.

2. Exercising at intensities below that prescribed by the coach and below that indicated as necessary to maintain fitness in previous studies was one contributing factor.

3. Other factors included the combination of a small team size and high rate of injuries.

In the future, it would be beneficial to test athletes prior to summer training in addition to the pre-season and post-season tests employed in this study to assess fitness changes at three time periods. Testing more successful teams at the Division I level would also provide useful information to compare differences in aerobic fitness among teams.
Intervention studies on female soccer players should be implemented to determine if improved RE and/or VO2max improves performance among this population.

Lennart Gullstrand (2009), a research publication, Measurement for Improvement of Running Capacity. Physiological And Biomechanical, submitted to Karolinska Institutet, Stockholm, Sweden.

Objectives

To broaden our understanding of the concept of running economy by introducing and evaluating new and easy-to-handle measurement methods. With these findings, integrated/simultaneous measurements of both physiological and biomechanical characteristics may be performed for more in-depth analysis and monitoring of training for middle- and long-distance runners.

The specific objectives were:

1. To evaluate whether the results of a lactate-threshold test on a treadmill may be influenced by a short rest interval for blood sampling instead of the more hazardous sampling during continuous running (in study I).
2. To measure running economy during treadmill and indoor track running with a previously validated (in study II) portable device and compare it’s precision to that of 3. Douglas bag results during treadmill running (Study III).
4. To investigate how well a single-point Vdisp from a convenient position transducer and accelerometer corresponds to the CoM Vdisp measured with the more sophisticated ProReflex optoelectric system (Study IV).
5. To evaluate the precision of stance-phase duration measured with a 40-beam infrared web during treadmill
running compared with that of a validated contact shoe (Study V).

Conclusions
1. The calculated threshold velocity and HR at 4mmol. L$^{-1}$ was not different when a 30s interruption for blood sampling was used compared to sampling at the end of each four-mini period during continuous running. The sampling-standing-still phase was more convenient and less risky for both athlete and test leader.
2. Reliable and stable measurements of oxygen uptake can be performed during running with the PMD device.
3. Running economy by means of submaximal oxygen uptake during steady state running is ~6.5% lower during track running compared to treadmill running, which most probably is related to differences in air resistance. Lactate threshold tests give similar results performed on treadmill and indoor track.
4. Changes and differences in $V_{\text{disp}}$ of CoM may be correctly measured with a singlepoint recording using a position transducer.
5. The temporal pattern during stride analysis can he accurately measured on treadmill using an infrared device giving a dense 40-beam web when mounted on the treadmill.

Meylan C., et al, (2009) Conducted study on Effects of in-season plyometric training within soccer practice on explosive actions of young players. In soccer, explosive actions such as jumping, sprinting, and changes of direction are essential to optimal performance not only in adults, but also in children's games. The purpose of the present
Investigation was to determine the influence of short-term plyometric training within regular soccer practice on explosive actions of early pubertal soccer players during the in-season. Fourteen children (13.3 +/- 0.6 years) were selected as the training group (TG) and 11 children (13.1 +/- 0.6 years) were defined as the control group (CG). All children were playing in the same league and trained twice per week for 90 minutes with the same soccer drills. The TG followed an 8-week plyometric program (i.e., jumping, hurdling, bouncing, skipping, and footwork) implemented as a substitute for some soccer drills to obtain the same session duration as CG. At baseline and after training, explosive actions were assessed with the following 6 tests: 10-meter sprint, agility test, 3 vertical jump tests (squat jump [SJ], countermovement jump [CMJ], contact test [CT] and multiple 5 bounds test [MB5]). Plyometric training was associated with significant decreases in 10-m sprint time (-2.1%) and agility test time (-9.6%) and significant increases in jump height for the CMJ (+7.9%) and CT(+10.9%). No significant changes in explosive actions after the 8-week period was recorded for the CG. The current study demonstrated that a plyometric program within regular soccer practice improved explosive actions of young players compared to conventional soccer training only. Therefore, the short-term plyometric program had a beneficial impact on explosive actions, such as sprinting, change of direction, and jumping, which are important determinants of match-winning actions in soccer performance.

The aim of the present study was to examine how explosive strength, kicking speed, and body composition are affected by a 12-week plyometric training program in elite female soccer players. The hypothesis was that this program would increase the jumping ability and kicking speed and that these gains could be maintained by means of regular soccer training only. Twenty adult female players were divided into 2 groups: control group (CG, n = 10, age 23.0 +/- 3.2 yr.) and plyometric group (PG, n = 10; age 22.8 +/- 2.1 yr.). The intervention was carried out during the second part of the competitive season. Both groups performed technical and tactical training exercises and matches together. However, the CG followed the regular soccer physical conditioning program, which was replaced by a plyometric program for PG. Neither CG nor PG performed weight training. Plyometric training took place 3 days a week for 12 weeks including jumps over hurdles, drop jumps (DJ) in stands, or horizontal jumps. Body mass, body composition, countermovement jump height, DJ height, and kicking speed were measured on 4 separate occasions. The PG demonstrated significant increases (p < 0.05) in jumping ability after 6 weeks of training and in kicking speed after 12 weeks. There were no significant times x group interaction effects for body composition. It could be concluded that a 12-week plyometric program can improve explosive strength in female soccer players and that these improvements can be transferred to soccer kick performance in terms of ball speed. However, players need time to transfer these improvements in strength to the specific task. Regular soccer training can maintain the improvements from a plyometric training program for several weeks.
Thomas et al, (2009) conducted a study on compare the effect of two plyometric training techniques on muscular power and agility in youth soccer players. Thirty males from as semi-professional football club's academy were randomly assigned to 6 weeks of depth jump (DJ) or counter movement jump (CMJ) training twice weekly. Participants in the DJ group performed drop jump with instructions to minimize ground – contact time while maximizing height. Participants in the CMJ group performed jumps from a standing start position with instructions to gain maximum jump height. Post training, both groups experienced improvements in vertical jump height (p<0.05) and agility time (p< 0.05) and no change in sprint performance (p<0.05). There were no differences between the treatments groups (p=0.05) the study concludes that both depth jump and counter movement jump (CMJ) plyometric are worthwhile training activities for improving power and agility in youth soccer players.

Brown G. A., (2010) conducted a study on Oxygen consumption, heart rate, and blood lactate responses to an acute bout of plyometric depth jumps in college-aged men and women. Although plyometric are widely used in athletic conditioning, the acute physiologic responses to plyometric have not been described. The purpose of this study was to investigate the oxygen consumption, heart rate, and blood lactate responses to a single session of plyometric depth jumps. Twenty recreationally trained college-aged subjects (10 men, 10 women) participated in a single session of 8 sets of 10 box depth jumps from a height of 0.8 m with 3 minutes of passive recovery between each set. Plyometric depth jumping
elicited 82.5 +/- 3.1% and 77.8 +/- 3.1% of the measured maximal oxygen consumption (O2max) for women and men, respectively, with no difference in oxygen consumption in ml/kg/min or percent O2max between sexes or sets. Heart rate significantly increased (p < 0.05) from 68.1 +/-2.9 beatsxmin-1 at rest to 169.6 +/- 1.2 beats/min-1 during depth jumping. Sets 5 to 8 elicited a higher (p < 0.05) heart rate (173.3 +/- 1.3 beatsxmin-1) than sets 1 to 4 (164.6 +/- 1.8 beatsxmin-1). Women exhibited a higher heart rate (p < 0.05) during sets 1 and 2 (169.9 +/- 2.8 beats/min-1) than men (150.7 +/- 4.4 beats/min-1). The blood lactate concentrations were significantly (p < 0.05) increased above resting throughout all sets (1.0 +/- 0.2 mmolxL-1 compared with 2.9 +/- 0.1 mmolxL-1), with no differences between sexes or sets. Plyometric depth jumping significantly increased oxygen consumption, heart rate, and blood lactate in both men and women, but no significant difference was found between the sexes. Plyometric depth jumping from a height of 0.8 m has similar energy system requirements to what Wilmore and Costill termed "Aerobic Power" training, which should enhance O2max, lactate tolerance, oxidative enzymes, and lactate threshold.

Berryman, N, Maurel, D, and Bosquet, L. (2010) conducted the study on effect of plyometric vs. dynamic weight training on the energy cost of running. The purpose of this study is to compare the effects of 2 strength training methods on the energy cost of running (Cr). Thirty-five moderately to well-trained male endurance runners were randomly assigned to either a control group (C) or 2 intervention groups. All groups performed the same endurance
training program during an 8-week period. Intervention groups added a weekly strength training session designed to improve neuromuscular qualities. Sessions were matched for volume and intensity using either plyometric training (PT) or purely concentric contractions with added weight (dynamic weight training [DWT]). We found an interaction between time and group (p < 0.05) and an effect of time (p < 0.01) for Cr. Plyometric training induced a larger decrease of Cr (218 ± 16 to 203 ± 13 ml/kg²/m²) than DWT (207 ± 15 to 199 ± 12 ml/kg²/m²), whereas it remained unchanged in C. Pre-post changes in Cr were correlated with initial Cr (r = 20.57, p < 0.05). Peak vertical jump height (VJHpeak) increased significantly (p < 0.01) for both experimental groups (DWT = 33.4 ± 6.2 to 34.9 ± 6.1 cm, PT = 33.3 ± 6.0 to 35.3 ± 3.6 cm) but not for C. All groups showed improvements (p < 0.05) in Perf3000 (C = 711 ± 107 to 690 ± 109 seconds, DWT = 755 ± 87 to 724 ± 77 seconds, PT = 748 ± 81 to 712 ± 76 seconds).

Plyometric training were more effective than DWT in improving Cr in moderately to well-trained male endurance runners showing that athletes and coaches should include explosive strength training in their practices with a particular attention on plyometric exercises. Future research is needed to establish the origin of this adaptation.

Chatzinikolaou A, et al., (2010) evaluated on the Time course of changes in performance and inflammatory responses after acute plyometric exercise. The objectives of the investigation were to study the inflammatory and performance responses after an acute bout of intense plyometric exercise during a prolonged recovery period. Participants were randomly assigned to either an experimental group (P, n = 12)
that performed intense plyometric exercises or a control group (C, n = 12) that rested. The delayed onset of muscle soreness (DOMS), knee range of motion (KROM), creatine kinase (CK) and lactate dehydrogenases (LDH) activities, white blood cell count, C reactive protein (CRP), uric acid (UA), cortical, testosterone, IL-6, IL-1b strength (isometric and isokinetic), and countermovement (CMJ) and static (SJ) jumping performance were measured at rest, immediately post exercise and at 24, 48, 72, 96, and 120 hours of recovery. Lactate was measured at rest and post exercise. Strength remained unchanged throughout recovery, but CMJ and SJ declined (p < 0.05) by 8-20%. P induced a marked rise in DOMS, CK, and LDH (peaked 24-48 hours post exercise) and a KROM decline. An acute-phase inflammatory response consisting of leukocytes (post exercise and at 24 hours), an IL-6, IL-1b, CRP, and cortical elevation (during the first 24 hours of recovery) and a delayed increase of UA (peaked at 48 hours) and testosterone (peaked at 72 hours) was observed in P. The results of this investigation indicate that performing an acute bout of intense plyometric exercise may induce short-term muscle damage and marked but transient inflammatory responses. Jumping performance seems to deteriorate for as long as 72 hours post exercise, whereas strength appears to remain unchanged. The acute-phase inflammatory response after a plyometric exercise protocol appears to follow the same pattern as in other exercise models. These results clearly indicate the need of sufficient recovery between successive plyometric exercises training sessions. Improving repeated sprint ability in young elite soccer players: repeated shuttle sprints vs. explosive strength training.
Ebben W. P. et al, (2010) evaluated the Periodized plyometric training is effective for women, and performance is not influenced by the length of post training recovery - effectiveness of a periodized plyometric training program and the impact of the duration of the post-training recovery period on countermovement jump performance. He studied on fourteen women subjects participated in a 6-week periodized plyometric training program. Ten women subjects served as non- training controls. All subjects' countermovement jump height, peak power, and body mass were assessed before and 2, 4, 6, 8, and 10 days after training. Kinetic data were obtained via a force platform using the average of 3 repetitions of the countermovement jump for each testing session. Jump height was 25.0% greater (p < or = 0.05) after training with no difference (p > 0.05) between recovery periods of 2, 4, 6, 8, or 10 days, for the training group. Peak power was 11.6-14.3% (p < or = 0.001) greater after training for the training group with no difference (p > 0.05) between recovery periods of 2, 4, 6, 8, or 10 days. Analysis revealed no significant difference (p > 0.05) for jump height or peak power from pre- to post test for the control group. Practitioners should prescribe per iodized plyometric programs with decreasing volume and increasing intensity to improve jump performance without a need for a post-training recovery period.

Khlifa, R, Aouadi, et al, (2010) conducted a study on The purpose of this investigation was to examine the effect of a standard plyometric training protocol with or without added load in improving vertical jumping ability in male basketball players. Twenty-seven players were randomly assigned to 3 groups: a control group (no plyometric training), plyometric
training group (PG), and loaded plyometric group (LPG, weighted vests 10-11% body mass). Before and after the 10-week training program, all the players were tested for the 5-jump test (5JT), the squat jump (SJ), and the countermovement jump (CMJ). The PG and LPG groups performed 2 and 3 training sessions per week, during the first 3 and the last 7 weeks, respectively. The results showed that SJ, CMJ, and 5JT were significantly improved only in the PG and LPG groups. The best effects for jumps were observed in LPG (p < 0.01), which showed significantly higher gains than the PG (p < 0.05). In conclusion, it appears that loads added to standard plyometric training program may result in greater vertical and horizontal-jump performances in basketball players.

**Santos EJ, Janeira MA., et al, (2010)** conducted the study on the Effects of Plyometric Training Followed by Detraining and Reduced Training Periods on Explosive Strength in Adolescent Male Basketball Players. The effects of plyometric training followed by detraining and reduced training periods on explosive strength in adolescent male basketball players. The aims of this study were to determine the effects of (a) plyometric training on explosive strength indicators in adolescent male basketball players and (b) detraining and reduced training on previously achieved explosive strength gains. Two groups were formed: an experimental and a control group. The former was submitted to a 10-week in-season plyometric training program, twice weekly, along with regular basketball practice. Simultaneously, the control group participated in regular basketball practice only. At the end of this period, the
experimental group was subdivided into 2 groups: a reduced training group and a detraining group. All participants were assessed on squat jump, countermovement jump, Abalakov test, depth jump, mechanical power, and medicine ball throw at the beginning and at the end of the 10-week in-season plyometric training and on weeks 4, 8, 12, and 16 of the in-season detraining and reduced training periods. In the first phase of the study, the experimental group significantly increased all the assessed indicators (p < 0.05). In the following phase and in general all the groups maintained the previously achieved results. In conclusion, plyometric training showed positive effects on upper- and lower-body explosive strength in adolescent male basketball players. Moreover, we can state that both detraining and a reduced training program indistinctly contribute to maintenance of strength levels. These results highlight the unique power that basketball-specific training seems to have on the sustainability and maintenance of sport performance.

Trzaskoma L, et al, (2010). Conducted a study on the effect of a short-term combined conditioning training for the development of leg strength and power. The aim of the study was to compare the effect of combined weight and pendulum training exercises with those isolated ones on muscle strength and vertical jump performance. A total of 38 young active men were divided into 4 groups performing different combinations of strength and power training and measured directly and 2 weeks after the training program. Weight training and pendulum swing exercises, involving lower body during dynamic bounces, were used. Results of 1 repetition maximum (1RM) in full squat and squat jump with the barbell, maximal
force measured during countermovement jump (CMJ), and hip and knee flexor and extensor isometric strength were analyzed. Significant differences \((p \leq 0.05)\) in strength test (1RM squat, hip and knee flexor and extensor strength) were found when performing weight training \((1RM-10.2\%; \text{maximal torques}-23.2\%)\). Positive significant increase \((p \leq 0.05)\) in all strength and power parameters \((\text{maximal torques-from } 2,468.9 +/- 387.4 \text{ to } 2,712.4 +/- 501.6 \text{ Nxm; } 1\text{RM squat-from 93.9 +/- 15.0 to 111.4 +/- 15.6 kg; CMJ power-from 3,050.7 +/- 478.5 \text{ to } 3,419.8 +/- 506.6 \text{ W; CMJ jump height-from 48.8 +/- 4.1 \text{ to } 53.4 +/- 3.0 cm})\) after the training program was found when combined training was used. Seated safety position during the pendulum swing is responsible for significant training effect with reduced loads. Plyometric pendulum swing training combined with traditional training can be an alternative, effective method to increase muscle strength and power during short pre or in-season mesocycles.


**Objectives**

The objectives of this study were to describe variability of pacing during a marathon and to determine if there is a relationship between variability of pacing and marathon performance.

**Conclusion**

The main purpose of the study was to describe the variability of pacing during a marathon. A secondary purpose of this study was to determine if there is a relationship between variability of pacing during a marathon and marathon
performance (i.e., finish time). Based upon the examination of $\text{Vel}_{\text{cov}}$ associated with marathon finish time segment, a relationship has been shown to exist between variability of pacing and marathon performance. The fastest runners exhibited the least variability while slower runners had greater variability in pacing. The results of this study have provided important knowledge into the pacing characteristics of the non-elite marathon runner. These findings are important to the future study of marathon pacing variability and development of ideal training protocols for runners of varying abilities.

Wallace BJ, et al, (2010) conducted study on Quantification of vertical ground reaction forces of popular bilateral plyometric exercises to quantify the vertical ground reaction forces (VGRFs) developed during the performance of popular bilateral plyometric movements. Fourteen power-oriented track and field men of collegiate and national level randomly performed 3 trials of 9 different bilateral plyometric exercises in a single testing session. Three depth drop (DD) and 3 depth jump (DJ) conditions from 30, 60, and 90 cm heights (DD30, DD60, and DD90 and DJ30, DJ60, and DJ90) were tested, in addition to vertical jump (VJ), standing long jump (SLJ), and 2 consecutive jump (2CJ) conditions. Peak impact VGRFs were normalized to body weight. Additionally, all conditions were compared against the VJ in an intensity index. The SLJ condition resulted in a significantly higher peak VGRF than the 2CJ condition ($p \leq 0.05$). 90DD, 90DJ, 60DD, and SLJ had a significantly greater peak VGRF (5.39, 4.93, 4.30, and 4.22 times body weight, respectively) than the VJ condition (3.34 times body weight). The 30DJ
condition had an insignificantly smaller peak VGRF (2.78 times body weight) when compared with the VJ. Practitioners may use these findings to more effectively progress athletes in these movements based on their intensities.

Wu YK et al. (2010) conducted the research on Relationships between three potentiation effects of plyometric training and performance. He has demonstrated briefly Relationships between three potentiation effects of plyometric training and performance. This study measured the potentiation effects of plyometric training [normalized electromyography (EMG) in triceps surae, stiffness and elastic energy utilization of the Achilles tendon] and investigated the correlations between these effects and performances [voluntary electromechanical delay (EMD) and jump height]. Twenty-one subjects were randomly assigned either to the control group (10 subjects: age 22.3+/−1.6 years) or to a training group (11 subjects: age 22.1+/−1.6 years) that performed 8 weeks of plyometric training. Results: As compared with the performances before training, normalized EMG in the soleus were significantly (P<0.001) increased after 4 and 8 weeks of training. Tendon stiffness, elastic energy storage, release and jump height determined after training were significantly increased (P<0.05), with a concomitantly reduced voluntary EMD (P=0.01). These variables also showed significant differences vs the control group (all P<0.05). The other variables remained unchanged. Correlations were observed between tendon stiffness and either voluntary EMD (r=−0.77, P=0.014) or jump height (r=0.54, P=0.031). Conclusions: Plyometric training specifically potentiated the normalized EMG, tendon stiffness and elastic
energy utilization in the myotendinous complex of the triceps. Although these changes are possibly essential determinants, only increases of tendon stiffness were observed to correlate with performance improvements.

Bonacci J, et al. (2011) conducted the study on neuromuscular adaptations to training, injury and passive interventions implications for running economy. The purpose of the study was to investigate the Performance of endurance sports such as running, cycling and triathlon from a physiological perspective. A strong relationship between running economy and distance running performance is well established. From this established base, improvements in running economy have traditionally been achieved through endurance training. More recently, research has demonstrated short-term resistance and plyometric training has resulted in enhanced running economy. This improvement in running economy has been hypothesized to be a result of enhanced neuromuscular characteristics such as improved muscle power development and more efficient use of stored elastic energy during running. Changes in indirect measures of neuromuscular control (i.e. Stance phase contact times, maximal forward jumps) have been used to support this hypothesis. These results suggest that neuromuscular adaptations in response to training (i.e. neuromuscular learning effects) are an important contributor to enhancements in running economy. However, there is no direct evidence to suggest that these adaptations translate into more efficient muscle recruitment patterns during running. Optimization of training and run performance may be facilitated through direct investigation of muscle recruitment
patterns before and after training interventions. There is emerging evidence that demonstrates neuromuscular adaptations during running and cycling vary with training status. Highly trained runners and cyclists display more refined patterns of muscle recruitment than their beginner counterparts. In contrast, interference with motor learning and neuromuscular adaptation may occur as a result of ongoing multidiscipline training (e.g. triathlon). In the sport of triathlon, impairments in running economy are frequently observed after cycling. This impairment is related mainly to physiological stress, but an alteration in lower limb muscle coordination during running after cycling has also been observed. Muscle activity during running after cycling has yet to be fully investigated, and to date, the effect of alterations in muscle coordination on running economy is largely unknown. Stretching, which is another mode of training, may induce acute neuromuscular effects but does not appear to alter running economy. There are also factors other than training structure that may influence running economy and neuromuscular adaptations. For example, passive interventions such as shoes and in-shoe orthoses, as well as the presence of musculoskeletal injury, may be considered important modulators of neuromuscular control and run performance. Alterations in muscle activity and running economy have been reported with different shoes and in-shoe orthoses; however, these changes appear to be subject-specific and non-systematic. Musculoskeletal injury has been associated with modifications in lower limb neuromuscular control, which may persist well after an athlete has returned to activity. The influence of changes in neuromuscular control
as a result of injury on running economy has yet to be examined thoroughly, and should be considered in future experimental design and training analysis.

Johnson BA, et al. (2011) conducted the study on a systematic review: plyometric training programs for young children. The purpose of this systematic review was to evaluate the efficacy and safety of plyometric training for improving motor performance in young children; to determine if this type of training could be used to improve the strength, running speed, agility, and jumping ability of children with low motor competence; and to examine the extent and quality of the current research literature. Primary research articles were selected if they (a) described the outcomes of a plyometric exercise intervention; (b) included measures of strength, balance, running speed, jumping ability, or agility; (c) included prepubertal children 5-14 years of age; and (d) used a randomized control trial or quasiexperimental design. Seven articles met the inclusion criteria for the final review. The 7 studies were judged to be of low quality (values of 4-6). Plyometric training had a large effect on improving the ability to run and jump. Preliminary evidence suggests plyometric training also had a large effect on increasing kicking distance, balance, and agility. The current evidence suggests that a twice a week program for 8-10 weeks beginning at 50-60 jumps a session and increasing exercise load weekly results in the largest changes in running and jumping performance. An alternative program for children who do not have the capability or tolerance for a twice a week program would be a low-intensity program for a longer duration. The research suggests that plyometric training is safe for children when
parents provide consent, children agree to participate, and safety guidelines are built into the intervention.

Monsef Cherif, et al. (2011) studied on The Effect of a Combined High-Intensity Plyometric and Speed Training Program on the Running and Jumping Ability of Male Handball Players. The aim of this study was to investigate the effect of a combined program including sprint repetitions and drop jump training in the same session on male handball players. Methods: Twenty-two male handball players aged more than 20 years were assigned into 2 groups: experimental group (n=11) and control group (n=11). Selection was based on variables "axis" and "lines", goalkeepers were not included. The experimental group was subjected to 2 testing periods (test and retest) separated by 12 weeks of an additional combined plyometric and running speed training program. The control group performed the usual handball training. The testing period comprised, at the first day, a medical checking, anthropometric measurements and an incremental exercise test called yo-yo intermittent recovery test. 2 days later, participants performed the Repeated Sprint Ability test (RSA), and performed the Jumping Performance using 3 different events: Squat jump (SJ), Countermovement jump without (CMJ) and with arms (CMJA), and Drop jump (DJ). At the end of the training period, participants performed again the repeated sprint ability test, and the jumping performance. Results: The conventional combined program improved the explosive force ability of handball players in CMJ (P=0.01), CMJA (P=0.01) and DJR (P=0.03). The change was 2.78, 2.42 and 2.62% respectively. No significant changes were noted in performances of the experimental group at the squat jump test
and the drop jump with the left leg test. The training intervention also improved the running speed ability of the experimental group (P=0.003). No statistical differences were observed between lines or axes. They concluded additional combined training program between sprint repetition and vertical jump in the same training session positively influence the jumping ability and the sprint ability of handball players.


Objectives:

1. The First objectives of the study to find out Effects of varied packages of plyometric training on selected motor ability components and physiological variables among college men students.

2. The second objectives of the study to find out superiority of the varied packages of plyometric training among college men students.

Conclusion

1. There was a significant difference among low intensity plyometric training, medium intensity plyometric training, high intensity plyometric training and control groups on selected motor ability components such as speed, leg explosive power, and muscular endurance.
2. There was a significant difference among low intensity plyometric training, medium intensity plyometric training, high intensity plyometric training and control groups on selected physiological variables namely resting pulse rate, VO2max and anaerobic power among college men students.

3. Significant improvements noticed on selected motor ability components such as speed, leg explosive power, and muscular endurance due to low intensity plyometric training, medium intensity plyometric training and high intensity plyometric training.

4. Significant improvements noticed on selected motor ability components such as speed, leg explosive power, and muscular endurance due to low intensity plyometric training, medium intensity plyometric training and high intensity plyometric training on selected physiological variables namely resting pulse rate, VO2 max and anaerobic power among men college students.

5. Among the experimental groups, high intensity plyometric training group significantly improved the selected dependent variables namely speed, leg explosive power, muscular endurance, resting pulse rate, VO2max and anaerobic power than that of low intensity plyometric training and medium intensity plyometric training groups.

Rubley MD, et al. (2011) conducted the study on the effect of plyometric training on power and kicking distance in female adolescent soccer players. The purpose of this study was to measure the effects of low-frequency, low-impact plyometric training on vertical jump (VJ) and kicking distance
in female adolescent soccer players. Sixteen adolescent soccer players were studied (age 13.4 ± 0.5 years) across 14 weeks. The control group (general soccer training only) had 6 subjects, and the plyometric training (general soccer training plus plyometric exercise) group had 10 subjects. All subjects were tested for VJ and kicking distance on 3 occasions: pre-test, 7 weeks, and 14 weeks. Data were analyzed using a 2 (Training) × 3 (Test) analysis of variance (ANOVA) with repeated measures on the factor test. No significant difference in kicking distance was found between groups at pre-test (p = 0.688) or 7 weeks (p = 0.117). The plyometric group had significantly greater kicking distance after 14 weeks (p < 0.001). No significant difference in VJ height was found between groups at pre-test (p = 0.837) or 7 weeks (p = 0.108). The plyometric group had a significantly higher VJ after 14 weeks (p = 0.014). These results provide strength coaches with a safe and effective alternative to high-intensity plyometric training. Based on these findings, to increase lower-body power resulting in increased VJ and kicking distance, strength coaches should implement once-weekly, low-impact plyometric training programs with their adolescent athletes.


Objectives:

1. To construct and validate the tool for measuring general anxiety in psychological area.
2. To construct and validate the tool for measuring self-confidence in psychological area.

3. To construct and validate the tool for measuring achievement motivation in psychological area.

4. To find the effectiveness of circuit and interval training on selected physical variables of the college men Kabaddi players in Kerala state.

5. To find the effectiveness of circuit and interval training on selected physiological variables of the college men Kabaddi players in Kerala state.

6. To find the effectiveness of circuit and interval training on selected psychological variables of the college men Kabaddi players in Kerala state.

7. Compare the effectiveness of circuit training and interval training on speed of the college men Kabaddi players in Kerala state.

8. Compare the effectiveness of circuit training and interval training on speed endurance of the college men Kabaddi players in Kerala state.

9. Compare the effectiveness of circuit training and interval training on agility of the college men Kabaddi players in Kerala state.

10. Compare the effectiveness of circuit training and interval training on explosive power of the college men Kabaddi players in Kerala state.
Conclusion

1. The study found that the physical variables like speed and speed endurance improved on both experimental groups, in comparison to control group after a 10 weeks training programme and the interval training group showed significant improvement in speed performance than circuit training group. thus the hypothesis regarding this area is accepted (H1).

2. The study found that the physical variables like agility, reaction time, abdominal strength and explosive power had improved on both experimental groups, in comparison to control group after a 10 weeks training programme and the circuit training group showed significant improvement in all the above physical variables as compared to interval training group. Thus the hypothesis regarding this area is being accepted (H2 & H3).

3. The study found that the physiological variables like resting heart rate and vital capacity had improved on both experimental groups, in comparison to control group after a 10 weeks training programme and the circuit training group showed significant improvement in the above physiological variables as compared to interval training group. Thus the hypothesis regarding this area is being accepted (H4).

4. The study found that the psychological variables like anxiety, self-confidence and achievement motivation had improved on both experimental groups, in comparison to
control group after a 10 weeks training programme. Thus the hypothesis regarding this area is being accepted (H5).

5. Based on the above conclusions it was found that the interval training workouts followed by the experimental group was found to be good at developing the speed variables for college men Kabaddi players in Kerala state (H1).

6. It was found that the circuit training workouts followed by the experimental group was found to be good at developing the strength variables for college men Kabaddi players in Kerala state (H2).

7. It was found that the interval and circuit training workouts followed by the experimental groups were found to be good at developing the endurance variables for college men Kabaddi players in Kerala state (H1&H3).

Shahram Alam, et al. (2012) conducted the study on The effect of plyometric circuit exercises on the physical preparation indices of elite handball player. The aim of this research was to find out the effect of plyometric circuit exercises on the physical preparation indices of elite handball players in the city of Behbahan. A total of 20 elite male athletes (aged 17-19) participated in this research. The participants were chosen non-randomly from a population of high school male students and they participated in four tests (the vertical jump - shuttle briskness – the medicine ball throw – the 30 meter speed run). After making them homogeneous, the participants were randomly divided into two groups, i.e. an
experimental group (plyometric circuit exercises) and a control group (only handball exercises). They participated in the exercises for 6 weeks with 3 sessions each week and each session lasted for 90 minutes. After completion of the course, both groups participated in a post-test. The participants' records were registered in 4 pre- and post-tests and compared. The results of the study revealed that 6 weeks of plyometric circuit exercise have a meaningful effect on the participants' records in four tests (the vertical jump - shuttle briskness - the medicine ball throw - the 30 meter speed run) and have caused improvements in the results of these four tests. Therefore, it seems that plyometric circuit exercises have had an effect on the physical preparation indices of handball players and can improve the athletes' performance in this field.

Marques M., et al. (2013) conducted the study on Does an in-Season 6-Week Combined Sprint and Jump Training Program Improve Strength-Speed Abilities and Kicking Performance in Young Soccer Players? The aim of this study was to examine the effect of a six-week combined jump and sprint training program on strength-speed abilities in a large sample of youth competitive soccer players. It was hypothesized that the experimental training group would enhance their jumping and sprinting abilities. Enhancement of kicking performance was also hypothesized due to an expected increase in explosive strength established by a plyometric and sprinting regimen. Fifty-two young male soccer players playing at the national level (aged 13.4 ± 1.4 years, body mass 53.4 ± 11.7 kg, body height 1.66 ± 0.11 m) took part in the study. Half of the group underwent the plyometric and sprint training
program in addition to their normal soccer training, while the other half was involved in soccer training only. The plyometric training group enhanced their running (+1.7 and +3.2%) and jumping performance (+7.7%) significantly over the short period of time, while the control group did not. Furthermore, both groups increased their kicking velocity after just six weeks of training (+3.3 vs. 6.6%). The findings suggest that a short in-season 6-week sprint and jump training regimen can significantly improve explosive strength in soccer-specific skills and that these improvements can be transferred to soccer kicking performance in terms of ball speed.

Gi Duck Park, JoonG chul lee, Juri lee (2014) conducted the study on The Effect of Low Extremity Plyometric Training on Back Muscle Power of High School Throwing Event Athletes. The Purpose of the study was to see the effect of plyometric training of high school athletes. The physical strength elements required for athletic throwing events include muscle strength, swiftness, agility, speed, flexibility, and physical balance. Although plyometric training and weight training are implemented as representative training methods for improving swiftness and agility, most studies of it have been conducted with players of other sports. [Subjects] The study subjects were 10 throwing event athletes attending K physical education high school. The subjects were randomly assigned to a control group of five subjects and an experimental group of five subjects. To analyze the body composition, an Inbody 3.0 instrument (Biospace, Korea) was used as experimental equipment to measure heights, weight, body fat percentages, and muscle masses and a Biodex system 4.0 (BIODEX, USA) was used to measure isokinetic muscle-
joint and lumbar muscle strengths. The plyometric training consisted of 15 techniques out of the training methods introduced in the 'Power up plyometric training'. The plyometric program was implemented without any training load three times per week during day-break exercises for the experimental group. The number of times and the number of sets were changed over time as follows: three sets of 10 times in the 1st–4th weeks, three sets of 15 times in the 5th–8th weeks, and five sets of 15 times in the 9th–12th weeks.

[Results] According to the ANCOVA results of lumbar extensor muscle strength at 60°/sec, the overall reliability of the model was significant. According to the ANCOVA results of lumbar flexor muscle strength at 60°/sec, the overall reliability of the model was significant. Plyometric training positively affected high school throwing event athletes. To summarize the study findings, the application of plyometric training with high intensity and loads improved the results of athletes who perform highly intensive exercises at normal times.

Huang PY, Chen WL, Lin CF, Lee HJ. (2014) conducted the study on Lower extremity biomechanics in athletes with ankle instability after a 6-week integrated training program. The purpose of the study was to investigate the effect of integrated plyometric and balance training in participants with FAI during a single-legged drop landing and single-legged standing position. The Design was Randomized controlled clinical trial and taken place in University motion-analysis laboratory. The subjects where thirty athletes with FAI were divided into 3 groups: plyometric group (8 men, 2 women, age = 23.20 ± 2.82 years; 10 unstable ankles), plyometric-balance (integrated)-training group (8 men, 2 women, age = 23.80 ±
4.13 years; 10 unstable ankles), and control group (7 men, 3 women, age = 23.50 ± 3.00 years; 10 unstable ankles). Intervention(s): A 6-week plyometric-training program versus a 6-week integrated-training program. Main Outcome Measure(s): Postural sway during single-legged standing with eyes open and closed was measured before and after training. Kinematic data were recorded during medial and lateral single-legged drop landings after a 5-second single-legged stance. Results: Reduced postural sway in the medial-lateral direction and reduced sway area occurred in the plyometric- and integrated-training groups. Generally, the plyometric training and integrated training increased the maximum angles at the hip and knee in the sagittal plane, reduced the maximum angles at the hip and ankle in the frontal and transverse planes in the lateral drop landing, and reduced the time to stabilization for knee flexion in the medial drop landing. Conclusions: After 6 weeks of plyometric training or integrated training, individuals with FAI used a softer landing strategy during drop landings and decreased their postural sway during the single-legged stance. Plyometric training improved static and dynamic postural control and should be incorporated into rehabilitation programs for those with FAI.

Park GD Lee JC, Lee J (2014) conducted the study on The Effect of Low Extremity Plyometric Training on Back Muscle Power of High School Throwing Event Athletes. The Purpose of the study was the physical strength elements required for athletic throwing events include muscle strength, swiftness, agility, speed, flexibility, and physical balance. Although plyometric training and weight training are implemented as representative training methods for improving
swiftness and agility, most studies of it have been conducted with players of other sports. [Subjects] The study subjects were 10 throwing event athletes attending K physical education high school. The subjects were randomly assigned to a control group of five subjects and an experimental group of five subjects. To analyze the body composition, an Inbody 3.0 instrument (Biospace, Korea) was used as experimental equipment to measure heights, weight, body fat percentages, and muscle masses and a Biodex system 4.0 (BIODEX, USA) was used to measure isokinetic muscle-joint and lumbar muscle strengths. The plyometric training consisted of 15 techniques out of the training methods introduced in the 'Power up plyometric training'. The plyometric program was implemented without any training load three times per week during daybreak exercises for the experimental group. The number of times and the number of sets were changed over time as follows: three sets of 10 times in the 1st -4th weeks, three sets of 15 times in the 5th-8th weeks, and five sets of 15 times in the 9th-12th weeks. [Results] According to the ANCOVA results of lumbar extensor muscle strength at 60°/sec, the overall reliability of the model was significant. According to the ANCOVA results of lumbar flexor muscle strength at 60°/sec, the overall reliability of the model was significant. [Conclusion] Plyometric training positively affected high school throwing event athletes. To summarize the study findings, the application of plyometric training with high intensity and loads improved the results of athletes who perform highly intensive exercises at normal times.

Ramirez-Campillo, et al. (2014) conducted study on Effects of plyometric training on endurance and explosive
strength performance in competitive middle- and long-distance runners. The purpose of this study was to examine the effect of a short-term plyometric training program on explosive strength and endurance performance in highly competitive middle and long distance runners. Athletes were randomly assigned to a control group (CG, n = 18, 12 men) and an explosive strength training group (TG, n = 18, 10 men). Drop jump (DJ) from 20 (DJ20) and 40 cm (DJ40), countermovement jump with arms (CMJA), 20-m sprint time, and 2.4-km endurance run time test were carried out before and after 6 weeks of explosive strength training. Also, the combined standardized performance (CSP) in the endurance and explosive strength test was analyzed. After intervention, the CG did not show any significant change in performance, whereas the TG showed a significant reduction in 2.4-km endurance run time (23.9%) and 20-m sprint time (22.3%) and an increase in CMJA (+8.9%), DJ20 (+12.7%), and DJ40 (16.7%) explosive performance. Strength training group also exhibited a significant increase in CSP, although the CG showed significant reduction. We conclude that properly programmed concurrent explosive strength and endurance training could be advantageous for middle, long-distance runners in their competitive performance, especially in events characterized by sprinting actions with small time differences at the end of the race.

2.3 Summary of the Literatures

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 his finding with regard to the problem. Further the literature collected in the study also helped the research scholar to summarize his study. The research studies reviewed were collected from journals available in the websites and some university libraries.

It is also observed from the reviews of literature that no research studies have been conducted in relation to plyometric training and traditional training followed by detraining on performance. This motivated the researcher to select this study.

The researcher carried on the present study on the basis of the above maintained related literature hoping that the present study will be of great help to a Physical education teacher.