Chapter II
REVIEW OF RELATED LITERATURE
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The reviews of related literature are very important in the process of the research because it forms the basic foundation upon which the future research is built. It gives a wide knowledge about the research problem and its background concepts and ideas which were the contribution from experts in our field. Previously proved theories and literature reveals the problem and also understanding of various approaches available for such a study. It also enables the selection of subject, selection of variables and research design to be used. It also provides ideas about the techniques of data analysis and interpretation for a study. The investigator has come to know that similar study has not been conducted before from previous studies by any research. The past literature also gives an idea about reliable and valid tools for the assessment of selected variables. All the above things may be accomplished only by doing systematic reviews of related literature.

REVIEWS OF LITERATURE ON PLYOMETRIC TRAINING

Ziv and Lidor (March 2010)\(^1\) have compared vertical jump(VJ) performance among the female and male volleyball players in a review of twenty four observational and eight experimental studies. In this study they found that higher VJ values were associated with players of better performing teams, the VJ performance increases due to strength and conditioning programs of plyometric training and also in order to maintain VJ performance, continuation of conditioning sessions throughout the season is important. The study also outlined some research limitations associated with the testing protocols and the strength and conditioning programs. The study also recommended that, the annual training programme should include plyometric training, avoidance of interruptions during the conditioning program, avoidance of over training during the pre-season and testing of VJ performance throughout the entire season.
Santos and Janeira (May 2010)\textsuperscript{2} have done a study on the effects of Plyometric Training followed by Detraining and Reduced Training Periods on Explosive Strength in Adolescent Male Basketball Players. The objectives of this study were to understand (a) the effects of plyometric training on explosive strength indicators in adolescent male basketball players and (b) the effects of detraining and reduced training on previously achieved explosive strength gains. In this study two groups were formed (a) an experimental groups and (b) a control group. The first group was subjected to a 10-week in-season plyometric training program, twice a week, along with regular basketball practice. Simultaneously, the control group was subjected to regular basketball practice only. At the end of the training period, the experimental group was further subdivided into 2 groups (a) a reduced training group and (b) a detraining group. All the 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 the 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.

Skurvydas, et. al., (April 2010)\textsuperscript{3} had investigated on effect of plyometric training on central and peripheral fatigue in boys. The aim of this study was to investigate the effect of high-intensity plyometric training (PT) on central and peripheral fatigue during exercise performed at maximal intensity in prepubertal boys. The boys ($n=13$, age 10.3+/-0.3 years) performed continuous 2-min maximal voluntary contractions (MVC)
before and after 16 high-intensity PT sessions (two training sessions per week, 30 jumps in each session, 20 s between jumps). The greatest effect of PT was on excitation-contraction coupling: twitch force increased by 323.2+/−210.8% and the height of a counter-movement jump increased by 36.7+/−11.7%, whereas quadriceps femoris (QF) muscle voluntary activation index, central activation ratio and MVC did not change significantly after PT. The thickness of QF increased by 8.8+/−7.9% after PT. Central fatigue increased significantly by about 15-20% after PT, whereas peripheral fatigue decreased significantly by about 10% during the 2-min MVC. Central fatigue and peripheral fatigue during the 2-min MVC were inversely related before PT, but this relationship disappeared after PT.

Ebben, et. al., (February 2010) had evaluated the plyometric exercises using time to stabilization. Plyometric exercises are frequently used in strength and conditioning and rehabilitation programs because the landing phase of these exercises requires dynamic stabilization. This study examined the differences in landing stability of a variety of plyometric exercises by assessing time to stabilization (TTS), its reliability, and sex differences therein. Forty-nine men and women performed a variety of plyometric exercises thought to represent a continuum of difficulty of dynamic stabilization during landing. Plyometric exercises included line hops, cone hops, squat jumps, tuck jumps, countermovement jumps, dumbbell countermovement jumps, and single leg countermovement jumps, each performed for 3 repetitions on a force platform. A 2-way mixed analysis of covariance with repeated measures for plyometric exercise type was used to evaluate the main effects for plyometric exercise type and the interaction between plyometric exercise type and sex for TTS. Subject jumping ability was evaluated as a covariate. Results revealed significant main effects for plyometric exercise type (p < or = 0.001) and for the interaction between plyometric exercise type and sex (p = 0.002). Bonferroni adjusted post hoc analysis demonstrated differences in TTS between a number of plyometric exercises for men and women. Reliability analysis revealed intraclass correlation coefficients ranging from 0.51 to 0.86 with no significant difference between trials (p > 0.05). Practitioners who use plyometrics to train dynamic stability should create programs that progress the intensity of the exercises based on the results of
this study. This study also demonstrated that TTS is moderately to highly reliable for a variety of jumping conditions for both men and women.

Meylan and Malatesta (December 2009)\textsuperscript{5} have conducted a study to determine the influence of short-term plyometric training for regular soccer practice on the explosive actions, such as jumping, sprinting and changes of direction on early pubertal soccer players. In this study an eight-week plyometric program (i.e., jumping, hurdling, bouncing, skipping, and footwork) was imparted as a substitute for some soccer drills among twenty five children with a mean age of 13.2 +/- 0.6 years. The group was subdivided into training group (TG) with fourteen children and control group (CG) with eleven children. It was found that plyometric training was associated with significant decreases in 10 meter sprint time (-2.1\%) and agility test time (-9.6\%) and significant increases in jump height for the countermovement jump (CMJ) (+7.9\%) and contact test (CT) (+10.9\%). Further no significant changes were recorded for the CG. Thus the study has demonstrated that a plyometric program during the regular soccer practice improves explosive actions of young players compared to conventional soccer training.

Sáez-Sáez de Villarreal, Requena and Newton (November 2009)\textsuperscript{6} have evaluated on the plyometric training improve strength performance: A meta-analysis. Majority of the research suggests plyometric training (PT) improves maximal strength performance as measured by 1RM, isometric MVC or slow velocity isokinetic testing. However, the effectiveness of PT depends upon various factors. A meta-analysis of 15 studies with a total of 31 effect sizes (ES) was carried out to analyse the role of various factors on the effects of PT on strength performance. The inclusion criteria for the analysis were: (a) studies using PT programs for lower limb muscles; (b) studies employing true experimental design and valid and reliable measurements; (c) studies including sufficient data to calculate ES. When subjects can adequately follow plyometric exercises, the training gains are independent of fitness level. Subjects in either good or poor physical condition, benefit equally from plyometric work, also men obtain similar strength results to women following PT. In relation to the variables of program design, training volume of less than 10 weeks and with more than 15 sessions, as well as the
implementation of high-intensity programs, with more than 40 jumps per session, were the strategies that seem to maximize the probability to obtain significantly greater improvements in performance (p<0.05). In order to optimize strength enhancement, the combination of different types of plyometrics with weight-training would be recommended, rather than utilizing only one form (p<0.05). The responses identified in this analysis are essential and should be considered by the strength and conditioning professional with regard to the most appropriate dose-response trends for PT to optimize strength gains.

De Villarreal et. al., (March 2009)\(^7\) had determined the variables of plyometric training for improving vertical jump height performance: a meta-analysis. Plyometric training improves vertical jump height (VJH). However, the effectiveness of plyometric training depends on various factors. A meta-analysis of 56 studies with a total of 225 effect sizes (ESs) was carried out to analyze the role of various factors on the effects of plyometrics on VJH performance. The inclusion criteria for the analysis were a) studies using plyometric programs for lower-limb muscles, b) studies employing true experimental designs and valid and reliable measurements, and c) studies including enough data to calculate ESs. Subjects with more experience in sport obtained greater enhancements in VJH performance (p < 0.01). Subjects in either good or bad physical condition benefit equally from plyometric work (p < 0.05), although men tend to obtain better power results than women after plyometric training (p < 0.05). With relation to the variables of performance, training volumes of more than 10 weeks and more than 20 sessions, using high-intensity programs (with more than 50 jumps per session), were the strategies that seemed to maximize the probability of obtaining significantly greater improvements in performance (p < 0.05). To optimize jumping enhancement, the combination of different types of plyometrics (squat jump + countermovement jump + drop jump) is recommended rather than using only 1 form (p < 0.05). However, no extra benefits were found to be gained from doing plyometrics with added weight. The responses identified in this analysis are essential and should be considered by strength
and conditioning professionals with regard to the most appropriate dose-response trends for optimizing plyometric-induced gains.

Thomas, French and Hayes (January 2009)\textsuperscript{8} have studied the effect of two plyometric training techniques on muscular power and agility in young soccer players, with an aim to compare the effects of the two training techniques. The plyometric training was given for six weeks among twelve subjects comprising of semi professional football players on the depth jump (DJ) and countermovement jump (CMJ). In the study, the participants in the DJ group performed drop jumps 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. After the 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). The study also found that, there were no differences between the treatment groups (p > 0.05). Therefore the study concludes that both DJ and CMJ plyometrics are vital training activities for improving power and agility among young soccer players.

Vissing, et. al., (November 2008)\textsuperscript{9} had conducted a study on muscle adaptations to plyometric training in comparison with conventional resistance training among untrained young men with an objective to compare changes in muscle strength, power, and morphology induced by these two types of trainings. At the end of twelve weeks progressive conventional resistance training imparted for eight subjects and plyometric training for seven subjects, it was found that the muscle strength of the subjects increased approximately by 20-30\% (1-3 RM tests) (p < 0.001). While the CRT show 50\% greater improvement in hamstring strength than PT (p < 0.01). Plyometric training increased maximum CMJ height (10\%) and maximal power (Pmax; 9\%). Moreover, CMJ and Pmax in ballistic leg press, increased to 17\% (p < 0.001). This was greater than CRT (p < 0.01), which only increased Pmax during the ballistic leg press by 4\% (p < 0.05). Further quadriceps, hamstring, and adductor whole-muscle cross-sectional area (CSA) increased equally (7-10\%) with CRT and PT (p < 0.001). No significant changes occurred for fiber CSA analysis. The study also found that myosin heavy-chain
IIX content decreased from 11 to 6%, with no difference between CRT and PT. The study concluded that, the gross muscle size increased both by PT and CRT, whereas only CRT seemed to increase muscle fiber CSA. It was also found that increase in maximal muscle strength were similar between groups, but muscle power increased because of PT training.

Marques, et. al., (July 2008)\textsuperscript{10} had 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 two 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.
de Villarreal, González-Badillo and Izquierdo (May 2008) have compared the 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., one day per week, two days per week, four days per week) associated with three different plyometric training volumes on maximal strength, vertical jump performance, and sprinting ability. Forty-two students were randomly assigned to one of four groups: control (n = 10, seven sessions of drop jump (DJ) training, one day per week, 420 DJs), 14 sessions of DJ training (n = 12, two days per week, 840 DJs), and 28 sessions of DJ training (n = 9, four days per week, 1680 DJs). The training protocols included DJ from three different heights 20, 40, and 60 cm. Maximal strength (one 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 differences were 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 (two 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 (four 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 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.
Ronnestad, et. al., (May 2008) had determined the prevalence the Short-term effects of strength and plyometric training on sprint and jump performance in professional soccer players. The purpose of this study was to compare 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 two groups. Group ST (n = 6) performed heavy strength training twice a week for seven 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 six to eight soccer sessions a week. Pretests and posttests were one 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 one 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 one RM 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 six to eight 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.

Salonikidis and Zafeiridis (January 2008) have administered on the effects of plyometric, tennis-drills, and combined training on reaction, lateral and linear speed, power, and strength in novice tennis players. 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 nine 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, four-m lateral and forward sprints, drop jump and maximal 
force. TDT improved all four-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 favorable changes 
to different aspects of fitness.

Burgess, et. al.,(August 2007) had compared the plyometric vs. isometric 
training influences on tendon properties and muscle output. The purpose of this study was 
to concurrently determine the effect that plyometric and isometric training has on tendon 
stiffness (K) and muscle output characteristics to compare any subsequent changes. 
Thirteen men trained the lower limbs either plyometrically or isometrically two to three 
times a week for a six-week period. Medial gastrocnemius tendon stiffness was measured 
in vivo using ultrasonography during ramped isometric contractions before and after 
training. Mechanical output variables were measured using a force plate during 
concentric and isometric efforts. Significant (p < 0.05) training-induced increases in 
tendon K were seen for the plyometric (29.4%; 49.0 +/- 10.8 to 63.4 +/- 9.2 N x mm (-1)) 
and isometric groups (61.6%; 43.9 +/- 2.5 to 71.0 +/- 7.4 N x mm(-1)). Statistically 
similar increases in rate of force development and jump height were also seen for both
training groups, with increases of 18.9 and 58.6% for the plyometric group and 16.7 and 64.3% for the isometric group, respectively. Jump height was found to be significantly correlated with tendon stiffness, such that stiffness could explain 21% of the variance in jump height. Plyometric training has been shown to place large stresses on the body, which can lead to a potential for injury, whereas explosive isometric training has been shown here to provide similar benefits to that of plyometric training with respect to the measured variables, but with reduced impact forces, and would therefore provide a useful adjunct for athletic training programs within a six-week time frame.

Markovic, et. al., (May 2007)\textsuperscript{15} had evaluated the 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 one of three 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
does conventional plyometric training. This study provides support for the use of sprint training as an applicable training method of improving explosive performance of athletes in general.

Markovic (June 2007)\textsuperscript{16} had done a research on 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-randomised 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 standardised units (ie, 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.

Saunders, et. al., (November 2006)\textsuperscript{17} had determined the short-term plyometric training improves running economy in highly trained middle and long distance runners. Fifteen highly trained distance runners VO(2)max 71.1 +/- 6.0 ml.min(-1).kg(-1), mean +/- SD) were randomly assigned to a plyometric training (PLY; n = 7) or control (CON; n = 8) group. In addition to their normal training, the PLY group undertook 3 x 30 minutes
PLY sessions per week for 9 weeks. Running economy (RE) was assessed during 3 x 4 minute treadmill runs (14, 16, and 18 km.h(-1)), followed by an incremental test to measure VO(2)max. Muscle power characteristics were assessed on a portable, unidirectional ground reaction force plate. Compared with CON, PLY improved RE at 18 km.h(-1) (4.1%, p = 0.02), but not at 14 or 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 quality assessment test (14%, p = 0.09), and a lower VO(2)-speed slope (14%, p = 0.12) after nine weeks of PLY. There were no significant differences in cardio respiratory measures or VO(2)max as a result of PLY. In a group of highly-trained distance runners, nine weeks of PLY improved RE, with likely mechanisms residing in the muscle, or alternatively by improving running mechanics.

Ratamess, et. al., (August 2007) had conducted a study to analyse the effects of resistance and combined plyometric/sprint training with the Meridian Elyte athletic shoe on the muscular performance of women. The subjects were divided into athletic shoe (AS) group with six subjects and Meridian Elyte athletic shoe (MS) group with eight subjects and the training was imparted for a period of ten weeks. The training was focused on one RM squat and bench press, vertical jump, broad jump, sprint speed, and body composition. It was found that there were significant increases in both AS group and MS group in one RM 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). Similarly the study found that in both groups there was decreases in peak times in 20, 40, and 60 meters sprint. However it was also, found that in sprint endurance there was a significant improvement at 60 meters in the MS group. It was also found that similar improvements in peak sprint speed and jumping ability, with either shoe. But with Meridian Elyte athletic shoe training, the high-intensity sprint endurance at 60 meters increased to a greater extent.
REVIEWS OF LITERATURE ON SWISS BALL TRAINING

Escamilla, et. al., (May 2010)\textsuperscript{19} had done a research on core muscle activation during Swiss ball and traditional abdominal exercises. Controlled laboratory study using a repeated-measures, counterbalanced design. The main objective of the study was to test the ability of 8 Swiss ball exercises (roll-out, pike, knee-up, skier, hip extension right, hip extension left, decline push-up, and sitting march right) and two traditional abdominal exercises (crunch and bent-knee sit-up) on activating core (lumbopelvic hip complex) musculature. Numerous Swiss ball abdominal exercises are employed for core muscle strengthening during training and rehabilitation, but there are minimal data to substantiate the ability of these exercises to recruit core muscles. It is also unknown how core muscle recruitment in many of these Swiss ball exercises compares to core muscle recruitment in traditional abdominal exercises such as the crunch and bent-knee sit-up. A convenience sample of 18 subjects performed five repetitions for each exercise. Electromyographic (EMG) data were recorded on the right side for upper and lower rectus abdominis, external and internal oblique, latissimus dorsi, lumbar paraspinals, and rectus femoris, and then normalized using maximum voluntary isometric contractions (MVICs). The result of the study indicate that EMG signals during the roll-out and pike exercises for the upper rectus abdominis (63\% and 46\% MVIC, respectively), lower rectus abdominis (53\% and 55\% MVIC, respectively), external oblique (46\% and 84\% MVIC, respectively), and internal oblique (46\% and 56\% MVIC, respectively) were significantly greater compared to most other exercises, where EMG signals ranged between 7\% to 53\% MVIC for the upper rectus abdominis, 7\% to 44\% MVIC for the lower rectus abdominis, 14\% to 73\% MVIC for the external oblique, and 16\% to 47\% MVIC for the internal oblique. The lowest EMG signals were consistently found in the sitting march right exercise. Latissimus dorsi EMG signals were greatest in the pike, knee-up, skier, hip extension right and left, and decline push-up (17\%-25\% MVIC), and least with the sitting march right, crunch, and bent-knee sit-up exercises (7\%-8\% MVIC). Rectus femoris EMG signal was greatest with the hip extension left exercise (35\% MVIC), and least with the crunch, roll-out, hip extension right, and decline push-up exercises (6\%-10\% MVIC). Lumbar paraspinal EMG signal was relative low (less than 10\% MVIC) for all exercises.
The roll-out and pike were the most effective exercises in activating upper and lower rectus abdominis, external and internal obliques, and latissimus dorsi muscles, while minimizing lumbar paraspinals and rectus femoris activity.

Marshall and Murphy (August 2006)\textsuperscript{20} had conducted a study to determine differences in electromyographic (EMG) activity of prime mover and abdominal muscles while performing squats, pushups, and double leg lowering with a Swiss ball. The study was conducted on twelve subjects and it was found that there was no difference between the surface conditions for muscle activity during the squat exercise. However, perceived exertion for the Swiss ball squat was lower among the individuals. Further the activity of the triceps and abdominals was highest during performing pushups on the Swiss ball. But the activity of rectus abdomens (RA) only increased during double leg lowering on the Swiss ball. Moreover Perceived exertion was high for the push up and leg-lowering exercise performed on the Swiss ball. The study attributes increased RA activity during double leg lowering to its role as a hip flexor. The lack of a rotation aspect to the task prevented increased oblique muscle activity. The study concludes that exercises performed with the Swiss ball appears to only increase muscle activity during exercises where the unstable surface is the primary base of support.

Cosio-Lima LM, et. al. (2003)\textsuperscript{21} have compared the effects of 5 weeks of physioball core stability and balance exercises with conventional floor exercises in women. The experimental group (n = 15) performed curl-ups and back extensions on the physioball while the control group (n = 15) performed the same exercises on the floor. Baseline and post-training tests included electromyography (EMG) recordings of the rectus abdominus and erector spinae muscles; abdominal, back, and knee strength measurements with the Cybex Norm System; and 2 unilateral stance balance tests. The physioball group was found to have significantly greater mean change in EMG flexion and extension activity (p = 0.04 and p = 0.01, respectively) and greater balance scores (p < 0.01) than the floor exercise group. No significant changes (p > 0.05) were observed for heart rate or Cybex strength measurements. Early adaptations in a short-term core exercise program using the physioball resulted in greater gains in torso balance and EMG
neuronal activity in previously untrained women when compared to performing exercises on the floor.

Marshall and Murphy (February 2005)\textsuperscript{22} have designed a study on core stability exercises on and off a Swiss ball. To assess lumbopelvic muscle activity during different core stability exercises on and off a Swiss ball. The subjects comprised of eighty university students. They performed four exercises on and off a Swiss ball: inclined press-up, upper body roll-out, single-leg hold, and quadruped exercise. The result of the study indicated that there was a significant increase in the activation of the rectus abdominus with performance of the single-leg hold and at the top of the press-up on the Swiss ball. This led to changes in the relation between the activation levels of the lumbopelvic muscles measured. The study concluded that although there was evidence to suggest that the Swiss ball provides a training stimulus for the rectus abdominus, the relevance of this change to core stability training requires further research because the focus of stabilization training is on minimizing rectus abdominus activity. Further support has also been provided about the quality of the quadruped exercise for core stability.

Stanton, Reaburn and Humphries (August 2004)\textsuperscript{23} have reviewed and found the effect of short-term Swiss ball training on core stability and running economy. The purpose of this study was to investigate the effect of a short-term Swiss ball training on core stability and running economy. Eighteen young male athletes (15.5 +/- 1.4 years; 62.5 +/- 4.7 kg; sigma skinfolds 78.9 +/- 28.2 mm; VO2max 55.3 +/- 5.7 ml.kg(-1).min(-1)) were divided into a control (n = 10) and experimental (n = 8) groups. Athletes were assessed before and after the training program for stature, body mass, core stability, electromyographic activity of the abdominal and back muscles, treadmill VO2max, running economy, and running posture. The experimental group performed two Swiss ball training sessions per week for 6 weeks. Data analysis revealed a significant effect of Swiss ball training on core stability in the experimental group (p < 0.05). No significant differences were observed for myoelectric activity of the abdominal and back muscles, treadmill VO2max, running economy, or running posture in either group. It appears
Swiss ball training may positively affect core stability without concomitant improvements in physical performance in young athletes. Specificity of exercise selection should be considered.

Sekendi , et. al., (November 2010) had investigate the effects of Swiss-ball core strength training on trunk extensor (abdominal)/flexor (lower back) and lower limb extensor (quadriceps)/flexor (hamstring) muscular strength, abdominal, lower back and leg endurance, flexibility and dynamic balance in sedentary women (n = 21; age = 34 ± 8.09; height = 1.63 ± 6.91 cm; weight = 64 ± 8.69 kg) trained for 45 minutes, 3 d-wk-1 for 12 weeks. Results of multivariate analysis revealed significant difference (p ≤ 0.05) between pre and postmeasures of 60 and 90° s trunk flexion/extension, 60 and 240° s-l lower limb flexion/extension (Biodex Isokinetic Dynamometer), abdominal endurance (curl-up test), lower back muscular endurance (modified Sorensen test), lower limb endurance (repetitive squat test), lower back flexibility (sit and reach test), and dynamic balance (functional reach test). The results support the fact that Swiss-ball core strength training exercises can be used to provide improvement in the aforementioned measures in sedentary women. In conclusion, this study provides practical implications for sedentary individuals, physiotherapists, strength and conditioning specialists who can benefit from core strength training with Swiss balls.

Marshall and Desai,(June 2010) have done a research on Swiss ball training. Although there is now some evidence examining the use of a Swiss ball during core stability and resistance exercises, this has commonly been performed using basic or isometric exercises. There is currently no evidence examining more advanced Swiss ball exercises. The purpose of this study was to determine whether or not muscle activity measured during advanced Swiss ball exercises was at an approximate intensity recommended for strength or endurance training in advanced, or novice individuals. After a familiarization session, 14 recreationally active subjects performed six different "advanced" Swiss ball exercises in a randomized order. The primary dependent variables in this study were the activity levels collected from anterior deltoid, pectoralis major, rectus abdominis (RA), external obliques, lumbar erector spinae, vastus lateralis (VL), and biceps femoris using surface electromyography. All signals were normalized to
maximal voluntary isometric contractions performed before testing for each muscle. The results of this study showed that the Swiss ball roll elicited muscle activity in triceps brachii (72.5+/-32.4%) and VL (83.6+/44.2%) commensurate with the intensity recommended for strength exercises in advanced trainers. Rectus abdominis activity was greatest during the bridge exercise (61.3+/28.5%, p<0.01). This was the only exercise to elicit RA muscle activity commensurate with a strength training effect. The remainder of the exercises elicited abdominal activity that would require a higher number of repetitions to be performed for an endurance training adaptation. Although this study has provided evidence for one advanced Swiss ball exercise providing a significant whole-body stimulus, the practical difficulty and risks of performing these more complicated Swiss ball exercises may outweigh potential benefits.

Goodman, et. al., (January 2008) have conducted a study on exercise or Swiss ball training are increasingly being used with conventional resistance exercises. There is little evidence supporting the efficacy of this approach compared to traditional resistance training on a stable surface. Previous studies have shown that force output may be reduced with no change in muscle electromyography (EMG) activity while others have shown increased muscle EMG activity when performing resistance exercises on an unstable surface. This study compared one RM strength, and upper body and trunk muscle EMG activity during the barbell chest press exercise on a stable (flat bench) and unstable surface (exercise ball). After familiarization, 13 subjects underwent testing for one RM strength for the barbell chest press on both a stable bench and an exercise ball, each separated by at least seven days. Surface EMG was recorded for five upper body muscles and one trunk muscle from which average root mean square of the muscle activity was calculated for the whole one RM lift and the concentric and eccentric phases. Elbow angle during each lift was recorded to examine any range-of-motion differences between the two surfaces. The results show that there was no difference in one RM strength or muscle EMG activity for the stable and unstable surfaces. In addition, there was no difference in elbow range-of-motion between the two surfaces. Taken together, these results indicate that there is no reduction in one RM strength or any differences in muscle EMG activity for the barbell chest press exercise on an unstable exercise ball
when compared to a stable flat surface. Moreover, these results do not support the notion
that resistance exercises performed on an exercise ball are more efficacious than
traditional stable exercises.

Willardson (August 2007)\textsuperscript{27} had reviewed in the study on the effectiveness of
greater core stability on sports performance by providing a foundation for greater force
production in the upper and lower extremities. The purpose of this review was to
critically examine core stability training and other issues related to this topic to determine
useful applications for sports conditioning programs. Based on the current literature,
prescription of core stability exercises should vary based on the phase of training and the
health status of the athlete. During preseason and in-season mesocycles, free weight
exercises performed while standing on a stable surface are recommended for increases in
core strength and power. Free weight exercises performed in this manner are specific to
the core stability requirements of sports-related skills due to moderate levels of instability
and high levels of force production. Conversely, during postseason and off-season
mesocycles, Swiss ball exercises involving isometric muscle actions, small loads, and
long tension times are recommended for increases in core endurance. Furthermore,
balance board and stability disc exercises, performed in conjunction with plyometric
exercises, are recommended to improve proprioceptive and reactive capabilities, which
may reduce the likelihood of lower extremity injuries.

Uribe, et. al., (April 2010)\textsuperscript{28} had investigated on muscle activation when
performing the chest press and shoulder press on a stable bench vs. a Swiss ball. The aim
of this study was to examine the effects of a stable surface (bench) vs. an unstable surface
(Swiss ball) on muscle activation when performing the dumbbell chest press and shoulder
press. Sixteen healthy men (24.19 +/- 2.17 years) performed 1 repetition maximum
(1RM) tests for the chest press and shoulder press on a stable surface. A minimum of 48
hours post 1RM, subjects returned to perform 3 consecutive repetitions each of the chest
press and shoulder press at 80% 1RM under 4 different randomized conditions (chest
press on bench, chest press on Swiss ball, shoulder press on bench, shoulder press on
Swiss ball). Electromyography was used to assess muscle activation of the anterior
deltoid, pectoralis major, and rectus abdominus. The results revealed no significant
difference in muscle activation between surface types for either exercise. This suggests that using an unstable surface neither improves nor impairs muscle activation under the current conditions. Coaches and other practitioners can expect similar muscle activation when using a Swiss ball vs. a bench.

Duncan (October 2009)\textsuperscript{29} had conducted a study on muscle activity of the upper and lower rectus abdominis with exercises performed on and off a Swiss ball. This study was conducted to analysis the differences in upper rectus abdominis (URA) and lower rectus abdominis (LRA) muscle activity. The exercises include the curl-up, Swiss ball curl-up, Swiss ball jackknife and Swiss ball rollout. The training was imparted to fourteen adults comprising of seven males, seven females. The results indicated that the URA activity was significantly greater than muscle activity of the LRA for the curl-up, Swiss ball curl-up and Swiss ball rollout. The LRA muscle activity was greater than URA during the jackknife exercise. The Muscle activity during the curl-up was significantly lower than muscle activity during the other exercises. The study conclude that the muscle activity was greater when exercises were performed on a Swiss ball in comparison to a stable surface and LRA muscle activity was maximized during the Swiss ball jackknife.

Corrêa and Bérzin (September 2008)\textsuperscript{30} have conducted a study to evaluate the recruitment of cervical muscles during nasal inspiration before and after breathing and postural exercises on the Swiss Ball in children with Mouth Breathing Syndrome (MBS). Surface electromyography from the sternocleidomastoid (SCM), sub-occipitals and upper Trapezius muscles was recorded during nasal inspiration, before and at the end of three months of the treatment. A physical therapy program consisting in muscular stretching and strengthening exercises along with naso-diaphragmatic breathing on the Swiss Ball were carried out for body posture realignment and respiratory training. Nineteen mouth breathing children, mean age of 10.6 years, both genres, were the subjects of this study. It was found in the study that, a significant decrease (p<0.01) in the electromyographic activity during nasal inspiration in all tested muscles after treatment (11.3-3.6\% in the SCM, 22.4-11.7\% in the sub-occipitals and 8.9-3.1\% in the upper Trapezius). At the end of the treatment, the assessed muscles reached lower activity electromyographic levels during nasal inspiration and they became closer of those in the quiet position.
Hoda and Oliver, (July 2005)\textsuperscript{31} have designed a study on trunk muscle activity during bridging exercises on and off a Swiss ball. A Swiss ball is often incorporated into trunk strengthening programs for injury rehabilitation and performance conditioning. It is often assumed that the use of a Swiss ball increases trunk muscle activity. The aim of this study was to determine whether the addition of a Swiss ball to trunk bridging exercises influences trunk muscle activity. Surface electrodes recorded the myoelectric activity of trunk muscles during bridging exercises. Bridging exercises were performed on the floor as well as on a labile surface (Swiss ball). The result of the study indicated that during the prone bridge the addition of an exercise ball resulted in increased myoelectric activity in the rectus abdominis and external oblique. The internal oblique and erector spinae were not influenced. The addition of a Swiss ball during supine bridging did not influence trunk muscle activity for any muscles studied. The study concluded that the addition of a Swiss ball is capable of influencing trunk muscle activity in the rectus abdominis and external oblique musculature during prone bridge exercises. Modifying common bridging exercises can influence the amount of trunk muscle activity, suggesting that exercise routines can be designed to maximize or minimize trunk muscle exertion depending on the needs of the exercise population.

Lehman ,et. al., (June 2005)\textsuperscript{32} had attempted to examine replacing a Swiss ball for an exercise bench causes variable changes in trunk muscle activity during upper limb strength exercises. The main aim of the study was to determine whether the addition of a Swiss ball to upper body strength exercises results in consistent increases in trunk muscle activation levels. The myoelectric activity of four trunk muscles was quantified during the performance of upper body resistance exercises while seated on both a stable (exercise bench) and labile (Swiss ball) surface. Participants performed the supine chest press, shoulder press, lateral raise, biceps curl and overhead triceps extension. A repeated measures ANOVA with post-hoc Tukey test was used to determine the influence of seated surface type on muscle activity for each muscle. The results of the study indicated that there was no statistically significant (p < .05) difference in muscle activity between surface conditions. However, there was large degree of variability across subjects suggesting that some individuals respond differently to surface stability. These findings
suggest that the incorporation of Swiss balls instead of an exercise bench into upper body strength training regimes may not be justified based only on the belief that an increase spinal stabilizing musculature activity is inherent. Biomechanically justified ground based exercises have been researched and should form the basis for spinal stability training as preventative and therapeutic exercise training regimes. The study concluded that selected trunk muscle activity during certain upper limb strength training exercises is not consistently influenced by the replacement of an exercise bench with a Swiss ball.

Behm, Anderson and Curnew, (August 2002)\textsuperscript{33} have done a study on muscle force and activation under stable and unstable conditions. The objective of this study was to determine differences in isometric force output, muscle activation (interpolated twitch technique), and electromyographic activity of the quadriceps, plantar flexors (PF), and their antagonists under stable and unstable conditions. Instability in subjects was introduced by making them perform contractions while seated on a "Swiss ball." Eight male subjects performed unilateral leg extensor (LE) and PF contractions while seated on a bench (LE), chair (PF), or a ball. Unstable LE and PF forces were 70.5 and 20.2\% less than their stable counterparts, respectively. Unstable quadriceps and PF activation averaged 44.3 and 2.9\% less than activation under stable conditions. Unstable antagonist/agonist ratios were 40.2 and 30.7\% greater than stable ratios in the LE and PF protocols, respectively. The greater decrements with LE can be attributed to the instability of only 2 points of floor contact, rather than 3 points of floor contact as with the PF. Swiss balls may permit a strength training adaptation of the limbs, if instability is moderate, allowing the production of overload forces.

Keogh, Aickin and Oldham, (February 2010)\textsuperscript{34} have determined on can common measures of core stability distinguish performance in a shoulder pressing task under stable and unstable conditions. The primary purpose of this study was to determine whether a range of static core stability (CS) measures could distinguish shoulder press performance in unstable vs. stable conditions. Thirty resistance-trained men gave informed consent to participate in this study. One-repetition maximum strength (from < 6 repetitions) was predicted in the seated shoulder dumbbell press performed in unstable (Swiss ball [SB]) and stable (back-support bench) environments. Three CS muscle
endurance tests were performed, with 4 CS ratios also calculated. The degree of strength decrement, referred to as the instability strength level (ISL), was calculated by dividing the predicted 1RM unstable score by the 1RM Stable score. All subjects were categorized as high (ISL > 0.90), moderate (0.85 < or = ISL < or = 0.90), or low (ISL < 0.85). Between-group differences for the high- and low-ISL groups were assessed using analysis of variance and effect sizes. Pearson product moment correlations were then performed to examine the relationships between the CS measures and the ISL for the entire group. No significant between-group differences (p = 0.132-0.999) or large effect sizes were observed for any of the CS measures. Trunk flexion endurance was the only CS measure significantly correlated to the ISL (r = 0.477). In line with muscular strength research, these results suggest that CS exhibits relatively high levels of task specificity and that CS performance in static single-joint exercises may not be highly related to that in more dynamic multijoint activities. Core stability training (with or without a SB) may therefore only lead to significant improvements in functional dynamic performance if the postures, mode and velocity of contraction performed in training, are similar to the competitive tasks.

**REVIEWS OF LITERATURE ON CIRCUIT TRAINING**

Taşkin (September 2009) had undertaken a research with an objective to determine the effect of circuit training directed towards motion and action velocity over the sprint-agility and anaerobic endurance. The training imparted on thirty two male physical education students with a mean age of 23.92 +/- 1.51 years. The group was divided into circuit training group (CTG; n = 16) and control group (CG; n = 16). A circuit training was conducted for ten weeks and at the end of the training it was found that there was a significant (p < 0.05) difference in sprint-agility between pre and post testing for the CTG (pretest = 14.76 +/- 0.48 seconds, posttest = 14.47 +/- 0.43 seconds). Pre and post training testing of participants included assessments of sprint-agility and anaerobic endurance. Following the training, there was also a significant (p < 0.05) difference in anaerobic endurance between pre- and post testing for the CG (pretest = 31.53 +/- 0.48 seconds, posttest = 30.73 +/- 0.50 seconds). The study concluded that the circuit training improved the sprint-agility and anaerobic endurance. The study used
Monteiro, et. al., (December 2008)\textsuperscript{36} had administered a study on the acute physiological responses to different circuit training protocols. The purpose of the study was to compare the acute physiological responses to a circuit weight training with the responses to a combined circuit training (weight training and treadmill run). The sample consisted of 25 individuals at an average state of training, including 10 men and 15 women, between 18 and 35 year old. There were selected 60 second sets of resistance exercises to the circuit weight training (CWT). Whereas in the combined circuit training (CCT), the subjects spent 30 seconds on the same resistance exercises and 30 seconds running on the treadmill. The rest intervals between the sets lasted 15 seconds. The analysis of variance (ANOVA) with 5\% significance level was utilized to the statistical analysis of the results. The result of the study indicated that CCT elicits a higher relative and absolute VO\textsubscript{2} and energy expenditure values than CWT for both genders (P<0.05). Regarding inter-gender comparison, males showed higher absolute and relative VO\textsubscript{2} and absolute energy expenditure values for both CWT and CCT than females (P<0.05). Females showed a significant greater \%VO\textsubscript{2}max value for both CWT and CCT. Due to the experimental conditions used to state both circuit training bouts (CWT and CCT), the VO\textsubscript{2} rate found was higher than the values reported by previous studies which used heavier weight lift. The study concluded that, CCT seems adequate to produce cardiovascular improvements and greater energy expenditure for both men and women, while CWT group classes are sufficient only for unfit women.

Smith, Hudson, Graitzer, and Raven, (2006)\textsuperscript{37} have suggested in their study that the terms of chronic adaptations appears to reduce the heart rate on account of resistance training, which is considered favorable. The research also show that on account of long term adaptations, there was no change up to a 11\% decrease in heart rate, which is attributed to the differences in intensity, volume, rest between sets, use of small vs. large muscle mass, duration of study and fitness level of the subjects. The study also suggest that regular participation in aerobic exercise often results in a decrease in resting heart rate by 5 to 25 beats per minute. Further the study indicates that the lowered resting heart
rate from exercise training is due to an increase in the parasympathetic nervous activity with a minor decrease in sympathetic nervous discharge.

Figueroa, et al.,(April 2011)\(^{38}\) have analysed in their study the relationship of combined resistance and endurance exercise training for improving breath holding time, arterial stiffness, blood pressure, and muscle strength in postmenopausal women. The study was conducted on twenty-four subjects aged between forty seven years and sixty eight years. The group was divided into no exercise group and combined exercise group. Combined resistance and endurance exercise training was imparted on the combined exercise group for twelve weeks. It was found that the combined circuit with combined resistance and endurance exercise improves arterial stiffness, hemodynamics, and muscle strength among the postmenopausal women. This study also provides evidence that combined training may have important health implications for the prevention of hypertension and frailty in postmenopausal women.

Pinto, et. al., (January 2010)\(^{39}\) have done a study to analyse the oxygen uptake (VO2), the heart rate (HR) and the energy expenditure (EE) during a typical slideboard exercise session and investigate differences on these variables when performing the same choreography at two different cadences (130 e 145 beats per minute - bpm). METHODS: The sample comprised 13 female university students \((21.77+/-.077\) years), apparently healthy and physically active, with past training in SE and mastering the technical levels one and two. The subjects performed randomly exercise sessions at 130 bpm and 145 bpm. The ventilatory response was measured by an open air circuit system (COSMED K4b2, Rome, Italy) and HR was measured by a portable monitor (Polar Wireless Double Electrode, Kempele, Finland). HR and VO2, during SE at 130 bpm, were 179.88+/-.834 bpm and 37.95+/-.371 mL/kg/min respectively. At 145 bpm SE means values were 182.08+/-.958 bpm and 39.67+/-.382 mL/kg/min respectively. EE during 130 bpm exercise was 10.60+/-.1.69 kcal/min and at 145 bpm was 10.90+/-.1.36 kcal/min. No differences were found between 130 and 145 bpm in none of the variables. We conclude that slideboard exercise cardio respiratory response does not seem affected by the rhythm
of execution. Moreover the EE associated with this type of exercise is above the literature reports for other types of group aerobic exercises.

Brentano, et. al., (November 2008)\textsuperscript{40} have conducted a study to analyze the effects of high-intensity Strength Training (ST) and circuit training on isometric strength (IS), upper limb dynamic strength (ULS) and lower limb dynamic strength (LLS), muscle activation of quadriceps (EMG quad), maximal oxygen uptake (VO2 max), time to exhaustion (TE), and bone mineral density (BMD). Twenty-eight postmenopausal women were divided into 3 groups: 1) ST group (STG, \( n = 9 \), 45-80% one repetition maximum (1RM), 2-4 sets, 20-6 reps), 2) circuit training group (CTG, \( n = 10 \), 45-60% 1RM, 2-3 sets, 20-10 reps), and 3) a control group (CON, \( n = 9 \), no exercise). Significance level was defined as \( p \leq 0.05 \) for all analyses. After 24 weeks of training, increases were observed in STG and CTG. However, whereas in the STG, the IS (32.7%), ULS (28.7%), LLS (39.4%), EMG quad (50.7%), VO2 max (22%), and TE (19.3%) increased, CTG showed changes only in IS (17.7%), ULS (26.4%), LLS (42.2%), VO2 max (18.6%), and TE (16.8%). BMD did not change in any experimental group. In the CON, there were no changes in the variables analyzed. Our results suggest that ST and circuit training positively affect postmenopausal women's muscular strength, muscular activation, and cardiorespiratory fitness, with no changes in BMD.

Wilmore, et. al., (May 2006)\textsuperscript{41} have conducted a study on efficacy of a 10-week program of circuit weight training to elicit specific physiological alterations was evaluated in a group of men (\( n = 16 \)) and a group of women (\( n = 12 \)), with an additional group of men (\( n = 10 \)) and a group of women (\( n = 11 \)) serving as controls. The circuit consisted of 10 stations performed on a Universal Gym, three circuits per day (approximately 22.5 min/day), three days/week. The subjects exercised at 40-55\% of 1-RM, executing as many repetitions as possible in 30 sec on each of the lifts, followed by a 15 sec rest as the subject moved to the next station. Following the training program, the experimental groups demonstrated significant increases in lean body weight, flexed biceps girth, treadmill endurance time, VEmax (women only), Vo2max in ml/kg-min
(women only), flexibility and strength. Significant decreases were found in selected skinfold measurements, and in resting heart rate (control group showed similar decreases). No change was found in body weight or in relative or absolute body fat. Generally, the women exhibited equal or greater changes when compared to the men for all variables assessed, which could be a function of their lower initial starting levels, or a more intense training program. It was concluded that circuit weight training is a good general conditioning activity, i.e., attends to more than one component of fitness.

George, et. al., (March 1997) have developed a maximal oxygen consumption (VO2/max) regression model derived strictly from self-reported non-exercise (N-EX) predictor variables. The VO2 max (mean +/- SD; 44.05 +/- 6.6 ml.kg-1.min-1) of 100 physically active college students (50 females, 50 males), aged 18 to 29 yr, was measured using a treadmill protocol and open circuit calorimetry. Questionnaire-based predictor variables used in the N-EX regression model included (a) the subject's perceived functional ability (PFA) to walk, jog, or run given distances, (b) habitual physical activity (PA-R) data, (c) body mass index (BMI), and (d) gender. BMI (kg.m-2) was computed from self-reported body weight in pounds and self-reported body height in feet and inches. The questionnaire-based N-EX regression model (R = 0.85, SEE = 3.44 ml.kg-1.min-1) developed in this study exceeded the accuracy of previously developed N-EX regression models and is comparable to many exercise-based regression models in the literature. Cross-validation using PRESS (predicted residual sum of squares) statistics demonstrated minimal shrinkage (R = 0.84, SEE = 3.60 ml.kg-1.min-1) of the present regression model. The PFA data were useful in explaining observed VO2 max variance (squared partial r2 = 0.155, P < 0.0001) and enhanced the ability of the N-EX regression model to accurately predict criterion VO2max. These results suggest that a questionnaire-based N-EX regression model provides a valid and convenient method for predicting VO2 max in physically active college students.

Taipale, et. al.,(July 2010) have examined effects of periodized maximal versus explosive strength training and reduced strength training, combined with endurance training, on neuromuscular and endurance performance in recreational endurance runners. Subjects first completed 6 weeks of preparatory strength training. Then, groups
of maximal strength (MAX, n=11), explosive strength (EXP, n=10) and circuit training (C, n=7) completed an 8-week strength training intervention, followed by 14 weeks of reduced strength training. Maximal strength (1RM) and muscle activation (EMG) of leg extensors, countermovement jump (CMJ), maximal oxygen uptake (VO(2MAX)), velocity at VO(2MAX) (vVO(2MAX)) running economy (RE) and basal serum hormones were measured. 1RM and CMJ improved (p<0.05) in all groups accompanied by increased EMG in MAX and EXP (p<0.05) during strength training. Minor changes occurred in VO(2MAX), but vVO(2MAX) improved in all groups (p<0.05) and RE in EXP (p<0.05). During reduced strength training 1RM and EMG decreased in MAX (p<0.05) while vVO(2MAX) in MAX and EXP (p<0.05) and RE in MAX (p<0.01) improved. Serum testosterone and cortisol remained unaltered. Maximal or explosive strength training performed concurrently with endurance training was more effective in improving strength and neuromuscular performance and in enhancing vVO (2MAX) and RE in recreational endurance runners than concurrent circuit and endurance training.

Guenette et.al., (2007)\(^\text{44}\) have conducted a research on the effect of endurance training on men and women during a cycle exercise. The main objective of the study is to assess expiratory flow limitation, end-expiratory lung volume, end-inspiratory lung volume, and the work of breathing. The study was conducted on eighteen subjects including eight men and ten women. It is found that the expiratory flow limitation occurred in nine females (90%) and three males (43%) during the final stage of exercise. Females had a higher relative end-expiratory lung volume (42+/-8 versus 35+/-5% forced vital capacity (FVC)) and end-inspiratory lung volume (88+/-5 versus 82+/-7% FVC) compared to males at maximal exercise (P<0.05). Further the study also found that the women also had a higher level of breathing compared to men across a range of ventilations. On an average, women had a level of breathing that was twice that of men at ventilations above 90 l min(-1). From the study it is found that expiratory flow limitation may be more common in females and they experience an increase in end-expiratory lung volume and end-inspiratory lung volume at maximal exercise when compared to males. The higher work of breathing in women is probably attributed to their smaller lung volumes and smaller diameter airways. The findings of the study suggest that women
utilize a greater majority of their ventilatory reserve compared to men and this is associated with a higher cost of breathing.

Scholtes, et. al., (June 2010) have evaluated the effectiveness of functional progressive resistance exercise (PRE) strength training on muscle strength and mobility in children with cerebral palsy (CP). Fifty-one children with spastic uni- and bilateral CP; (29 males, 22 females; mean age 10 y 5 mo, SD 1 y 10 mo, range 6 y 0 mo-13 y 10 mo; Gross Motor Function Classification System levels I-III) were randomized to the intervention group (n=26) or the control group (n=25, receiving usual care). The intervention group trained for 12 weeks, three times a week, on a five-exercise circuit, which included a leg-press and functional exercises. The training load progressively increased based on the child's maximum level of strength, determined by the eight-repetition maximum. Muscle strength (measured with hand-held dynamometry and a six-repetition maximum leg-press test), mobility (measured with the Gross Motor Function Measure, two functional tests, and a mobility questionnaire), and spasticity (measured by the appearance of a catch) were evaluated before, during, directly after, and 6 weeks after the end of training by two blinded research assistants. The result of the study show that directly after training, there was a statistically significant effect (p<0.05) on muscle strength (knee extensors +12% [0.56 N/kg; 95% confidence interval {CI} 0.13-0.99]; hip abductors +11% [0.27 N/kg; 95% CI 0.00-0.54]; total +8% [1.30 N/kg; 95% CI 0.56-2.54]; six-repetition maximum +14% [14%; 95% CI 1.99-26.35]), but not on mobility or spasticity. A detraining effect was seen after 6 weeks. The study concluded that the twelve weeks of functional PRE strength training increases muscle strength up to 14%. This strength gain did not lead to improved mobility.

Nikolić and Ilić (March 1992) have assessed maximal aerobic power (VO2max) in trained and untrained 15-year-old boys. The trained subjects (18) were junior swimmers from a Belgrade swimming team, and the untrained ones (12) were from a Belgrade high school. VO2max was directly measured during progressive cycle ergometer exercise using open circuit spirometry. No significant differences in height, mass, percentage fat and vital capacity were noted between the trained and untrained
groups. Maximal aerobic power (overall, relative and in relation to lean body mass) in absolute values, and expressed per kilogram of body mass and lean body mass, was 31.5%, 21.2% and 20.6%, respectively, higher in the trained than in the untrained group (P less than 0.05). These data suggest that physical training significantly increases maximal aerobic power in young subjects.

Ferreira, et. al., (April 2010) have examined the trends on circuit resistance training in sedentary women: body composition and serum cytokine levels. Exercise can generate alterations in body composition and modulate the immune system. The objective of this study was to verify whether a circuit resistance training (CRT) protocol can increase lean body mass (LM), and reduce fat body mass (FM) and the percent of FM (%FM) of sedentary women, without inducing inflammatory responses, indicated by serum cytokine levels. The initial hypothesis was that CRT would improve body composition, without changing serum cytokine levels. The study consisted of 14 healthy, sedentary women, aged 33-45 years (mean +/- SD, 40.23 +/- 3.98 years), with a normal body mass index. They participated in 3 sessions per week of CRT, which included 2 rounds in 9 stations with 1 set of 8-12 repetition maximum at each station, for 10 weeks. During the 10-week CRT period, participants maintained their pre training nutritional standard. Body composition was analysed with dual-energy X-ray absorptiometry both pre- and post-training. Blood samples were collected after 96 h of rest pre- and post-training, and 5 min, 24 h, and 48 h after the second and last training sessions to measure serum cytokine levels by flow cytometry. The nutritional standard was accompanied throughout the study period with 24-h dietary recall. Increases in LM (35.937 +/- 4.926 to 39.130 +/- 4.950 kg) and decreases in FM (21.911 +/- 8.150 to 17.824 +/- 4.235 kg) and %FM (37.10 +/- 10.84 to 31.19 +/- 6.06), without concurrent changes in serum cytokine levels, and in the nutritional standard (alpha = 0.05). The proposed CRT improved body composition and did not induce any changes in serum cytokine levels characteristic of the inflammatory response in women.

Paoli, et. al., (March 2010) have conducted a study to determine the prevalence of the effects of three distinct protocols of fitness training on body composition, strength...
and blood lactate. The objective of the study was to determine the physiological effects of circuit training performed at different intensities on body composition, strength and blood lactate in middle-aged subjects who had recently undergone only minimum physical training. Forty participants (aged 50-65) were assigned to a control group (CG) or to one of the three exercise treatment groups: Endurance Group (EG), Circuit-Low Intensity Group (CLG), Circuit-High Intensity Group (CHG). The three groups exercised three times per week, 50 min per session for 12 wk using EG (N.=10), CLG (N.=10) or CHG (N.=10). The result showed that among the three groups, CHG group had the greatest reductions in body weight (BW), percentage of fat mass (FM), waistline, blood lactate (produced at 100 Watt during sub maximal test) and greater improvement in 6RM in horizontal leg press and underhand cable pull downs. The study concluded that high-intensity exercise combined with endurance training in the circuit training technique is more effective than endurance training alone or low intensity circuit training in improving body composition, blood lactate.

N. Takeshima, et. al., (October 2004) have examine the effects of a programmed accommodating circuit exercise (PACE) program consisting of aerobic exercise and hydraulic-resistance exercise (HRE) on fitness in older adults. Thirty-five volunteers were randomly divided into two groups [PACE group (PG) 8 men and 10 women, 68.3 (4.9) years, and non-exercise control group (CG) 7 men and 10 women, 68.0 (3.4) years). The PG participated in a 12-week, 3 days per week supervised program consisting of 10 min warm-up and 30 min of PACE (moderate intensity HRE and aerobic movements at 70% of peak heart rate) followed by 10 min cool-down exercise. PACE increased (P<0.05) oxygen uptake (V(\cdot)O(2)) at lactate threshold [PG, pre 0.79 (0.20) l min(-1), post 1.02 (0.22) l min(-1), 29%; CG, pre 0.87 (0.14) l min(-1), post 0.85 (0.15) l min(-1), -2%] and at peak V(\cdot)O(2) [PG, pre 1.36 (0.24) l min(-1), post 1.56 (0.28) l min(-1), 15%; CG, pre 1.32 (0.29) l min(-1), post 1.37 (0.37) l min(-1), 4%] in PG measured using an incremental cycle ergometer. Muscular strength evaluated by a HRE machine increased at low to high resistance dial settings for knee extension (9-52%), knee flexion (14-76%), back extension (18-92%) and flexion (50-70%), chest pull (6-28%) and press (3-17%), shoulder press (18-31%) and pull (26-85%), and leg press (21%). Body fat (sum of three
skinfolds) decreased (16%), and high-density lipoprotein cholesterol (HDLC) increased (10.9 mg dl(-1)) for PG. There were no changes in any variables for CG. These results indicate that PACE training incorporating aerobic exercise and HRE elicits significant improvements in cardiorespiratory fitness, muscular strength, body composition, and HDLC for older adults. Therefore, PACE training is an effective well-rounded exercise program that can be utilized as a means to improve health-related components of fitness in older adults.

Banfi et.al., (2006) have conducted a study on haematological parameters and possible modifications in elite rugby players. During the study blood samples were collected from the members of the Italian National rugby team at four consecutive training camps. Due to turnover of the subject, the data could be obtain for nineteen subjects it was found that the iron and transferrin saturation were stable, while ferritin increased at the end of the season. The modifications of the soluble transferrin receptor (STFR) were linked to those of red blood corpuscles haematocrit: STFR increased after training and during the competition period when haemoglobin and haematocrit decreased, and decreased at the end of the season. Haemoglobin, red blood corpuscles and haematocrit showed slightly higher levels during the first part of the season and decreased in the second half, when physical demand was high, as demonstrated by biochemical additional tests. Leucocytes and platelets were stable throughout the season. It is found in the study that haematological and iron metabolism parameters fall within physiological range of values. The study indicated that reticulocytes and STFR are the most sensitive parameters for studying the iron metabolism of the athletes.

Wehrlin et.al., (2006) have done a research on effect of live high-train low on haemoglobin mass (Hbmass) and red cell volume (RCV) in elite endurance athletes is still controversial. The study was conducted on altitude group (AG) of ten Swiss national team orienteers of five men and five women who lived at 2,500 meters for eighteen hours per day and trained at 1,800 and 1,000 meters above sea level for 24 days. A control group comprising of three men and four women is also formed to analyse the before and after altitude of Hb mass, RCV (carbon monoxide rebreathing method), blood, iron, and performance parameters. The study revealed that in the subjects of AG Hbmass (805+/-
209 vs. 848+/−225 g; P<0.01) and RCV (2,353+/−611 vs. 2,470+/−653 ml; P<0.01), increased. Whereas there was no change for the CG (Hbmass: 849+/−197 vs. 858+/−205 g; RCV: 2,373+/−536 vs. 2,387+/−551 ml). In the AG, Serum erythropoietin (P<0.001), reticulocytes (P<0.001), transferrin (P<0.001), soluble transferrin receptor (P<0.05), and hematocrit (P<0.01) increased, whereas ferritin (P<0.05) decreased. The study inferred that the changes were associated with an increased maximal oxygen uptake (3,515+/−837 vs. 3,660+/−770 ml/min; P<0.05) and improved 5,000-m running times (1,098+/−104 vs. 1,080+/−98 s; P<0.01) from pre- to postaltitude. The study also found that living at 2,500 m and training at lower altitudes for 24 days increases Hbmass and RCV. These changes indicate that it contributes to enhanced performance of elite endurance athletes.

Kaikkonen et. al., (August2004) have done a research on effects of a 12-week low resistance circuit weight training (CWT) on cardiovascular and muscular fitness were studied in 90 healthy sedentary adults. The subjects were randomized into three equally fit groups: CWT, Endurance (END) and Control (CON) according to their maximal aerobic power (VO2max). Both training groups exercised for 12 weeks, 3 days a week in sessions of 40 min, with a heart rate (HR) level of 70-80% HRmax. The CWT group trained with air resistance machines. Heart rate was controlled by setting the speed of movement. The END group walked, jogged, cross-country skied or cycled. The net differences (between pre- and posttraining changes) between the CWT and CON groups was statistically significant for VO2max (2.45 ml x min(-1) x kg(-1), 95% CI 1.1; 3.8), for abdominal muscles (3.7 reps, CI 0.3; 7.1), for push-ups (1.1 reps, CI 0.2; 2.1), and for kneeling (2.25 reps, CI 0.01; 4.5). The net difference (between pre- and posttraining changes) in the END and CON groups was statistically significant for VO2max (2.75 ml(-1) x min(-1) x kg(-1), 95% CI 0.9; 4.6), and kneeling (3.0 reps, CI 0.7; 5.3). Low resistance CWT with moderately hard HR level has effects comparable to an equal amount of endurance training on the cardiovascular fitness of sedentary adults. The CWT model was benefical also on muscular fitness. Based on the results, this type of exercise can be recommended for beginners because of its multilevel effects.

Chtaram, et. al., (July 2008) examined 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 1 of 5 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 5 repetitions run at the velocity associated with Vo2max (Vo2max) for a duration equal to 50% of the time to exhaustion at Vo2max; recovery was for an equal period at 60% Vo2max. 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-jump test and countermovement jump were measured pre- and post-testing. The study found no significant differences 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 (p < 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 study also found that intrasession sequence did not influence the adaptive response of muscular strength and explosive strength and power.
REFERENCE


