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REVIEW OF RELATED LITERATURE
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Review of Related Literature

Sports training has undergone vast changes in recent years. Traditional method of training has been facilitated with various new approaches. It has been necessary for sports trainer, coaches and athlete to understand the emerging concept and to adopt and make use of these approaches for excellence in sports. One of the new approaches in sports training includes core training which has become widely acceptable because, of its role in increasing strength stability improved sports techniques and injury prevention.

The benefits of core training start from improved posture to increased performance. Correct posture is of vital importance in day to day life and also for elite sports performance. It is well known that the antigravity muscles are larger core muscles, which plays important role in maintaining athletic posture (Gambetta, 1996). Core is important because it is the anatomical location in the body where the centre of gravity is located, thus where movement stems and is also important to maintain posture during functional activities, if core is unstable it leads to improper posture and movement and it is also reported that static postural alignment, facilitates appropriate and anticipatory postural activity of the feed forward system (Clark et al., 1998, 2000 & King 2000, 2005).

Segal et al. (2004) studied effect of pilates training on flexibility and body composition of 47 adults, Fingertip-to-floor, distance truncal lean body mass was measured by bioelectrical impedance. It was also noted that flexibility was improved by pilates training but it has limited effects on body composition, health status and posture. It was recommended that study needed larger sample sizes and an appropriate control group for the comparative assessment.
Faigenbaum & Mediate (2006) studied the effect of medicine ball training on fitness performance, it was concluded that medicine ball training significantly improved the fitness variables ie Flexibility, Shuttle Run, Long Jump, Medicine ball, Abdominal curl, Medicine ball toss and Medicine ball push up performance. Core strengthening helps to increase strength and performance and also provides the neuromuscular control in working condition and also improves sports performance techniques (Roetert, 2002 and Akulthota & Nadler, 2004).

Marshall & Murphy (2006) investigated electromyography activity, while performing squats, pushups, and double leg lowering with a Swiss ball. It was concluded that activity of triceps and abdominals was highest while performing pushups on the Swiss ball hence concluded that Swiss ball exercise only increased muscle activity.

Escamilla et al. (2010) in a study with 8 swiss ball exercise and two traditional abdominal exercises reported that to activate upper and lower rectus abdominis, external and Internal oblique and latissiumus dorsi muscles, roll out and pike exercise were very effective whereas these exercises minimized activity of lumbar paraspinals & rectus femories.

Willardson (2007) studied core stability training to modify some traditional resistance exercises to give an application to sports conditioning program. He suggested modifications like stable surface to unstable surface, sitting to standing exercises, machines to free weight exercises etc. Recommendations included free weight exercises on stable surfaces to increase core strength and power. Core strengthening helps to increase strength and performance and also provides the neuromuscular control in working condition and also improves sports performance techniques (Roetert 2002, Akulthota & Nadler, 2004).
Tracy et al. (1999) studied a group of 75-yr-old men and women for muscle quality before and after a unilateral leg strength training program. After sets of heavy-resistance knee extensor strength training exercise men exhibited greater absolute increases in the knee extension than the women. However, both men and women showed the similar percent increases in the 1-RM test, muscle volume and a significant increase in MQ was observed in both trained leg groups and in untrained leg. Findings of the study suggest that there might be similar neuromuscular adaptations in both gender groups. After 9 wk of ST, older men exhibit greater absolute increases in muscle volume and 1-RM strength then the similar aged women showing no gender difference.

Kirkendall & Garrett (1998) studied the training programme on skeletal muscles associated with the aging process. Gradual loss of muscle function, and age-related alterations in skeletal muscle function mark the process of aging and is dependent on age factor, different sex and the level of muscle activity. Aging mostly affects muscles loose both cross-sectional area and fiber numbers and sometimes denervation of fibers may occur. The combined effect of these leads to an increased percentage of type I fibers in older adults but, the aerobic enzymes start to decline with age. Aged skeletal muscle appears to be weakening and resistance training help in minimizing or even reverse of the losses. It was concluded that aerobic capacity of muscle was improved by endurance training, and resistance training can improve muscle of central nervous system and increase muscle mass. Therefore, a lifetime physical activity encourages maintaining the structure and function of skeletal muscle.

Lyndon et al. (1999) noticed the effects of resistance training (RT) and chromium picolinate (CrPic) supplementation on 18 men of age group of 56–69 yr while studying skeletal muscle size, strength, and power and whole body composition. A high-intensity RT Program were designed and CrPic (17.8μmol Cr/day) administered or a low-Cr placebo for 12 wk. 50-fold increased urinary Cr
excretion were noticed while consuming CrPic and muscle strength has also been seen to be increased. It was concluded that although RT program had significant and independent effects on the muscle size, strength, power development or lean body mass accretion during a RT program in older men, but high-dose of CrPic supplement had not enhanced these measurements.

Hunter et al. (2004) reviewed the benefits of resistance training associated with daily life as quality life, functional status and health among older adults. The commonly occur problems in older people are Sarcopenia and loss of strength. In older adults reduced strength and endurance and increased difficulty in physical activity affect the Quality of life. the resistance training in older adults helps in increasing strength and muscle mass and Muscle quality, but till now the date poorly understood involvement of satellite cells to support hypertrophy of mature myofibres. Also, increases power, reduction in difficulty of performing daily tasks, enhanced energy expenditure has been seen when resistance training has been given to the older adults.

Wasardson (2007) suggested that sports performance is facilitated through core stability training by providing a greater force production in the upper and lower extremities. Bouisset et al. (1981) reported that the stability of the pelvis and trunk is necessary for all movement of the extremities. Many researchers have reported effect of core training on various performance variables. Core muscles training Program found to enhance the dynamic balance in tennis athletes (Samson, 2005) and improved running times (Sato et al., 2009).

Significant effect of Core strength training on the ability to create and transfer the forces on athlete extremities for vertical jump, broad jump and push press has been noticed (Shinkle, 2010). Sato & Mokha, (2009) studied core strength training influence on 5000-m performance, running kinetics, lower-extremity stability, and in runners, and reported that the core training of experimental group showed faster times in 5000-m run but no influence on ground
reaction forces (GRF) or lower leg stability, and concluded, core strength training volume can have a significant effect on running performance.

**Stanton et al. (2004)** investigated the effect of Swiss ball training on running economy and core stability and concluded that core stability positively affected by Swiss ball training without improvements in physical performance.

**Cosio et al. (2003)** studied the effect of physioball ball and floor exercises in women. The experimental group were tested for back extension, Curls on physioball ball muscles and balance. Control group performed the same on floor. Electromyography (EMG) was used for record rectus abdominus, erector spinae, abdominal back and knee strength measurements, and 2 unilateral stance balance test were measured. It was concluded that physioball ball training improved EMG flexion ($P=0.04$) extension ($P=0.01$) activity and trunk balance ($P=0.00$) in experimental group.

**Shinkle et al. (2012)** conducted study on 25 collegiate football players who performed medicine ball throws in static and dynamic positions and concluded that through core strength training athlete’s ability was improved to create and transfer the forces to the extremities. To improve core strength and stability, plank exercises are considered an adequate method of training the core. Plank exercise puts the athletes in a nonfunctional static position that is very rarely replicated in the demands of sport-related activities. The core is the center portion of the body and should be trained accordingly.

**Reed et al. (2012)** in a review article on core stability training, focused to develop trunk muscles and hip muscles with comprehensive training, which is an integral part of athletic development, to assess direct relation to athletic performance. It was concluded that specific core stability training provides minor benefits, various studies have reported contradictory results and there exist lack of a consistency in measurement of outcomes.
Bliss & Teeple (2005) reported core muscles training and various stability exercises have become key components for athletes and sports persons. The core muscles transfer the force from the core and act as a bridge between both the limbs, which is called powerhouse. Stability initially requires that neutral spine must progress beyond the neutral zone in a controlled manner. Studies have reported relationship between core and injury occurrence. It was suggested that core training initially shall develop exercise for specific core muscle and then progress to include complex movements as per principle of training.

Marshall & Murphy (2005) designed a study of core stability with different Swiss ball exercises for university student. Lumbopelvic muscle activity were assessed by electromyography. Four different exercises were performed on swiss ball: upper body roll-out, quadruped exercise, inclined press-up and single-leg hold. The result of the study indicated that activation of the rectus abdominus significantly increases with performance of the single-leg hold and 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 swiss ball training stimulate the rectus abdominus muscles.

Sandstedt et al. (2013) in a study of 12 week exercise program concluded that weight bearing exercise, muscle strength training with free weight and rope improved muscle strength in the legs, which lead to increase performance in children and adolescent.

Sekendi et al. (2010) investigated the effects of Swiss-ball training on trunk extensor, lower back, quadriceps flexor, hamstring muscular strength, abdominal, leg endurance, flexibility and dynamic balance in sedentary population. Results of multivariate analysis revealed that significant difference were found between pre and post measures. The results suggested that Swiss-ball training exercises can be used in training program for the improvement of quadriceps flexor, hamstring muscular strength, & abdominal and leg endurance, flexibility etc. in sedentary women.
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Marshall and Desai (2010) conducted research on Swiss ball training using basic or isometric exercises. In this study 14 subjects performed six different advance Swiss ball exercises randomly. The dependent variables of this study were the activity levels which is recorded by electromyography and collected from pectoralis major, anterior deltoid, rectus abdominis, lumbar erector spinae, external obliques, vastus lateralis VL, and biceps femoris. The results showed that Swiss ball roll obtained muscle activity in triceps brachii (72.5 ± 632.4%) and VL (83.6 ± 44.2%) matching with the intensity required for strength exercises in advanced trainers. Rectus abdominis activity was maximum during the bridge exercise (61.3 ± 28.5%, p ≤ 0.01). It can be concluded that only single advanced Swiss ball exercise elicit a major whole-body stimulus, but degree of difficulty and risks of performing these more complicated Swiss ball exercises may outweigh potential benefits.

Uribe et al. (2010) investigated muscle activation while performing the dumbbell chest press and shoulder press on stable bench as compared with Swiss ball. Their study revealed that either of the exercise, between surface types has no significant difference in muscle activation. It was suggested that using an unstable surface has no effect on improvement on muscle activation under certain conditions. Sports personnels like coaches can obtain similar muscle activation using stable benches or Swiss ball. Akuthota (2004) in a review article concluded that physiologic functions of body are majorly supported by core, and treatment and prevention of various musculoskeletal conditions has theoretical basis of core strengthening.

Risk of lower extremity injury in athletes can be measured in terms of core stability. It was reported that males produced greater hip abduction, hip external rotation and quadrates lumbarorum measures than the females and in injury prevention the core stability play an important role (Leetun et al., 2004, 2010). They found that there is significant difference in trunk flexor and extensor endurance. Workers, working in awkward positions for long, can be suggested for
strengthening and functional movement of core enhancement programs to prevent injuries (Bates et al., 2007 & Mehrboni et al., 2010). Athletic and non-athletic patient with mechanical non-specific low back pain were subjected to core stability training by (Mehrboni et al., 2010).

The ability and functional strength of the neuromuscular system is essential dependent on core strength. The core musculatures helps to reduce force, produce force and stabilizes dynamics of the kinetic chain as well as protect it from unwanted functional movements forces (Richardson et al., 1992, Gribble, 2003 & Hodges et al., 1996). Handzel, (2008) highlighted the importance of training to develop a strong and stable core. Incorporation of even just a few core training movements into the current program can help in reducing risk of injury as well as overall performance. The essential focus of strength training is increasing the rate of force development. Furthermore, training with certain goals can be given to induce hypertrophy and increased maximal strength to certain individuals. It should be noted that incorporation of functional and specific core training movements can lead to greatest success in sports.

Nikolaidis (2010) investigated the core stability of three groups of football players having two male and one female group. With respect to trunk flexors endurance, no significant differences were found between-groups. Although, female players showed significantly superior flexors-to-extensors ratio indicating that women may have higher trunk extensors endurance.

Roelants et al. (2004) conducted a study to see the effect of 24 weeks "whole body vibration" training and fitness training on muscle strength & body composition with Forty-eight untrained females. The whole body vibration groups (N=18) and the fitness group (N=18). The resistance training program included leg extension and dynamic leg press exercises. Groups were trained 3 times weekly. The control group (N = 12). After 24 weeks training program fat free
mass increased significantly in the whole body vibration group (+ 2.2 %) only. A significant strength gain was recorded in the whole body vibration group and in the fitness group. It was concluded that whole body vibration training induces a gain in knee-extensor strength combined with a small increase in fat free mass. The gain in strength is comparable to the strength increase following a standard fitness training program consisting of cardiovascular and resistance training.

_**Hibbs (2008)**_ studied Optimizing Performance by Improving Core Stability and Core Strength. It was concluded that Core strengthening exercises are very popular in rehabilitation programmes despite little scientific evidence existing as to their efficacy on improving subsequent performance. This include joint stability exercises, contraction exercises (concentric, eccentric and isometric), balance training, perturbation (proprioceptive) training, plyometric (jump) exercises (plyometric training emphasises loading of joints and muscles eccentrically before the unloading concentric activity) and sport-specific skill training.

_**Peate et al. (2007)**_ studied effect of core strength training for injury prevention and prediction. The sample comprised 433 firefighters who performed functional movement screen for the assessment of asymmetries. Participation in training for core resulted in reduced lost time due to injuries by 62% and the number of injuries by 42% over a twelve month period as compared to a historical control group. It was suggested that core strength training and the program of functional movement enhancement is very important and significant to prevent injuries in workers who are to work in awkward body postures.

Core provides major support to physiologic function. The imperative effect of core stability and its motor control on initiation of functional limb movements are recommended in athletics. All practitioners, athletes and coaches use core
strengthening techniques to improve fitness level, performance and to prevent injury. Core strengthening is also known as lumbar stabilization. Core strength training used as a therapeutic treatment regimen for low back pain (Akuthota, Ferreiro, Moore & Fredericson, 2008).

Sidar & Venugopal (2008) reported that Core muscles strength highly correlated with fitness components such as muscle endurance, anaerobic power, explosiveness, leg strength etc. Wagner (2010) reported that isometric core strength correlated more strongly with the tests of soccer sport performance. Athlete should start sports specific movement in an attempt to maximize use of kinetic chain for energy transfer as well as for avoidance of injuries. Performing exercises with the CORE X system helps in increased muscle activation, along with effective performance with an athletic stance. Training and maintaining a core neutral while in movement from an athletic ready position should form the center point while imparting sports specific training. It is been suggested that sports personnel may incorporate the CORE X system in training program to obtain core strengthening benefits (Oliver et al., 2010).

Ziv and Lidor (2010) compared vertical jump performance among the male and Female volleyball players in a review of twenty four observational and eight experimental studies. It was concluded that higher Vertical jump values were associated with players of better performing teams, due to strength and conditioning programs of plyometric training. Four recommendations for volleyball and strength and conditioning coaches were given: (a) Plyometric training should be included in the annual training program; (b) Interruptions in the conditioning program during the season should be avoided; (c) Overtraining during the pre-season should be avoided; and (d) Vertical jump performance should be tested throughout the entire season.
Cissik (2011) suggested core training for combating the lower back injuries and other lower back issues, its treatment and improvement of performance of sports personal. He was not able to conclude the benefits of core training on performance of athletes, to be a significant part of strength and conditioning program. He also remarked the effectiveness of these exercise on treatment of injuries.

Pierce, Nichols & Hermon (2007) in a study with 15 different core exercises for school going children reported that core training improves fitness level of the students including balance and the better posture, which leads to efficient movement and performance. He also concluded that core training transcend, age barrier and it is an ideal activity for all student. Swaney & Hess (2003) reported that core stabilization program might improve isometric posture without effecting dynamic stability. Core should be trained correctly to provide optimal movement within the whole body (Myers, 2001).

Muthukrishnan et al. (2010) examined the effect of core stability exercise and conventional physiotheraphy regime in patient chronic low back pain on altered postural control parameters it was concluded that there was 20% absolute risk reduction of flare-up during intervention and 40% absolute risk reduction for resolution of back pain after core instability exercises, and significant improvement were shown in distribution of ground reaction force, which shows change in low transfer patterns during perturbation similar to healthy controls group.

McGill (2010) focused on core training to improve movement patterns and flexibility to enhance the appropriate blend of stiffening. It was suggested implementation of core training to execute better performance of athletes as well as non-athletes and prevention from injuries. It was also recommended that combinations of training like pull, push, lift etc. for performance enhancement. The activity of superficial core muscles in terms of electromyographic activity (EMG) during different exercises like seated, standing, bilateral and unilateral
dumbbell shoulder presses, found that the neuromuscular activity of the superficial core muscles can be enhanced by standing exercises and unilateral exercises instead of seated and bilateral exercises (Saeterbakken & Finland, 2011).

Roetert et al. (1996) found significant relationship between isokinetic trunk testing and functional movement patterns in tennis. The isokinetic and functional trunk strength tests would be useful additions to a tennis training program.

Okada et al. (2011) conducted a study to determine the relationship between core stability, functional movement, and performance with 28 healthy individuals (age = 24.4 ± 3.9 yr, height = 168.8 ± 12.5 cm, mass = 70.2 ± 14.9 kg). The test was performed in 3 categories: extension [EXT], core stability (flexion [FLEX], right and left lateral and functional movement screen (FMS). The study concluded that core training increased the performance of the players and also recommended that core and functional movement are important to include in a regular training program, especially for prevention of injuries, but it should not be the primary emphasis of any training program.

Behm et al. (2010) in a review article suggested that to train core musculature ground based free weight exercise lift should be the base for athlete and non athlete.
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Literature survey highlights the effectiveness of core strength training in sports performance & in fitness improvements but the absence of literature in Indian context has lead scholar to take up the present study to develop insight into the core training concept.