INTRODUCTION

Sports are timeless activity ones that human have enjoyed since at least ancient times, as exemplified by the Greek Olympic Games. Indeed, ethnographic and archeological evidence such as cave painting and the accounts of early European explorers, indicate sports may well go back to the very beginning of humankind.

Physical education and the science of athletic performance can trace their roots too long before ancient Greek culture ever begins to glorify the human body & athletic prowess. Expanding our knowledge of personal well-being and athletic performance has been humanity’s quest for centuries. Physical activity is need of the human body & it should not be denied. Modernization and Mechanization prevent involvement in physical activity, but games and sports fulfill this requirement.

At one time in western civilization, during the height of Athenian era in ancient Greece, sports was considered an essential element of the arts & humanity. The enriched fulfilled person was one who continually strove for an integrated balance of physical, mental and spiritual excellence. The body was valued equally with the mind & spirit.
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During the present century sports have become a cultural & social phenomenon of great magnitude and complexity. It has penetrated most, if not all of our social institutions including education, economics arts, politics and international diplomacy etc\(^1\) (John W. Loy, 1978, p. 3)

Sportsman & spectators are very clear about value and significance of sports. That is why the scientific investigation of the performance of sport is playing a vital role in achieving top class performance\(^2\). (A.Buchim, 1975)

Winning laurels at international sports has become a prestigious issue linked with the political system and as such nation vie with others to produce top class sportsman for international competition. For this research is systematically conducted to identify the factors that help in achieving the level of skill, which a player can attain through proper coaching & evaluation\(^3\). (Shukla, 1982)

Modern competitive sports have above & beyond the athletic activities of the past, in terms of their business value, physical ability of the athlete and the level of importance that is placed on success. In the

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1. John W. Loy, Barry D, McPherson & Gerald Kenyon, Sports and Social system(Addison-wesley Publishing co. Inc. 1978)
main professional sports, athletes are often multi-million dollar commodities and any hindrance to their performance is a loss of industry.

India known for its fanaticism for sport, started its sports odyssey long back during the great Vedic era of India where sports like hunting, boating, swimming, martial art, horse riding, wrestling etc. were played. The young generation is mad behind the game of cricket. In the present era lot is required to give appropriate place to games & sports in the society. However physical activity is the need of the human body & it should not be denied. Modernization and Mechanization prevent involvement in physical activities, but games and sports fulfill this requirement.

The origins of cricket lie somewhere in the Dark Ages - probably after the Roman Empire, almost certainly before the Normans invaded England, and almost certainly somewhere in Northern Europe. All research concedes that the game derived from a very ancient, widespread and uncomplicated pastime by which one player served up an object, be it a small piece of wood or a ball, and another hit it with a suitably fashioned club\(^4\). (Wikipedia)

How and when this club-ball game developed into one where the hitter defended a target against the thrower was simply not known. Nor is there any evidence as to when points were awarded dependent upon how far the hitter was able to dispatch the missile; nor when helpers joined the two-player contest, thus beginning the evolution into a team game; nor when the defining concept of placing wickets at either end of the pitch was adopted.

Cricket was first played in southern England in the 16th century. By the end of the 18th century, it had developed into the national sports of England. The expansion of British Empire lead to cricket being played overseas & by mid 19th century the first international matches are being played.

In initial days “Test cricket” was having more craze & where the batsman use to dominate the bowlers. Cricket enters into a new era in 1963 when English counties introduced the limited over variant, as it was sure to produce the result. Limited over cricket was lucrative and the number of matches increased. The first limited over’s international game was played in 1971 between Australia & England at Melbourne Cricket
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ground. In the 21\textsuperscript{st} century, a new limited over’s form 20-20 has made an immediate impact & made the game more competitive and demanding\textsuperscript{4}.

The game underwent major development in the 18\textsuperscript{th} century & became the national sports of England. Bowling evolved around 1760 when bowler began to pitch the ball instead of rolling it towards the batsman. The 19\textsuperscript{th} century saw “Underarm bowling Replaced by the first roundarm and then overarm bowling\textsuperscript{4}.

Pace bowlers, or fast bowlers or paceman, rely on speed to get a batsman out. This type of bowler can be further classified according to the speed rate at which they bowl the ball on average. Most pace bowlers are medium-fast to fast in top level cricket. In general, bowlers of this type are described as right arm or left arm "fast", or right arm or left arm "fast-medium", and so on.

Swing bowlers are pace bowlers who, apart from being fast, also use the seam of the ball to make it travel in a curved path through the air. This is further encouraged by systematically polishing one side of the ball while allowing the other side to become roughened and worn. The differing airflow around the two sides will cause the ball to swing in the air, towards the roughened side. By changing the orientation of the ball in
his hand, a bowler may therefore, cause the ball to swing into or away from the batsman.

**Spin bowlers** or spinners impart rotation to the ball to get a batsman out. The spin on the ball makes its movement hard to predict, particularly when it bounces, hence spin bowlers try to deceive batsmen into making a mistake. Speed is not crucial in spin bowling, and spinners tend to bowl in the slow-medium to the medium-slow range, around 45-55 mph. There are two broad categories of spin bowling: wrist spin and finger spin.

**Fast bowling** some time known as pace bowling is one of the two main approaches i.e. spin and fast bowling. Fast bowling required more of power, strength, & endurance of the player. The primary aim of fast bowling is to bowl cricket ball at high speed and to induce it to bounce off the pitch in erratic fashion or move side way through the air, factors which make it difficult for the batsman to hit the ball cleanly\(^5\).

A legend former Australian fast bowler and international bowling coach, Dennis Lillee, stated that \textit{“Fast bowling is the toughest job on the cricket field and that a pace bowler had to be stronger than the rest}\(^5\).

of the team”. Calling fast bowling the toughest job on a cricket field, Lillee stated that a paceman had to be stronger than the rest. "He is like the centre-forward in a football team. No matter how fit you are, you can always get injured. Some withstand the pain more, others succumb. As you get tired, your technique can break down." He believed that trunk strength was vital for paceman and recommended Swiss ball exercise. A fast bowler should be perfectly balanced at the point of delivery⁶.


Success in the fast bowling is determined by a combination of many factors, one imperative variable being the speed at which the ball is released. A quick ball release speed reduces the time available for the batsman to make a correct decision about the path of the ball, thus increasing the demands on the effector mechanism responsible for executing the exact shot. An optimal fast bowling technique could be defined as one that allows the bowler to bowl fast with relatively low injury risk⁷. (Bartlett RM, 1996)

Cricket is now a day’s becoming a more demanding game. Bowlers are supposed to bowl with as much speed as possible. That

requires enough strength and stability. The importance of the function of the central core of the body for stabilization and force generation in all sports activities is increasingly recognized. ‘Core stability’ is seen as being pivotal for an efficient biomechanical function to maximize force generation and minimize joint loads in all types of activities ranging from running to throwing. However, there is less clarity about what exactly constitutes ‘the core’, either anatomically or physiologically, and physical evaluation of core function is also varied. (Kibler WB, 2006)

The importance of function of the central core of the body for stabilization and force generation in all sports activities is increasingly recognized. ‘Core stability’ is seen as being pivotal for the efficient biomechanical function to maximize power generation and minimize joint loads in all types of activities ranging from running to throwing. However, there is less clarity about what exactly constitutes ‘the core’, either anatomically or physiologically, and physical evaluation of core function is also variable.

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8 Kibler W.B., Press J, Sciascia A, The role of core stability in athletic function (Journal of sports medicine in 2006, 189-198)
In a recent article on speed in young athletes by (Grazzo, 2004)\textsuperscript{9} it was said that speed camps and speed-based training programs are currently among the most popular and trendy activities within the youth sports industry. He said, \textit{``The core musculature is comprised of all muscles (major and minor) from just below the pelvis to right around the scapula. All of these muscles need to be conditioned in order to maximize the potential speed of the young athlete. Speed requires core stability.'''}

'Core stability' is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities. Core muscle activity is best understood as the pre-programmed integration of local, single-joint muscles and multi-joint muscles to provide stability and produce motion. This results in proximal stability for distal mobility, a proximal to distal patterning of the generation of force, and the creation of interactive moments that move and protect distal joints. Evaluation of the core should be dynamic, and include evaluation of the specific functions (trunk control over the

\textsuperscript{9} Brian J. Grazzo in developingathletics.com 2004
planted leg) and directions of motions (three-planar activity)\(^8\). (Kibler WB, 2006)

All movements of the body either originate in or are coupled through the trunk, and this coupling action is created by an active and strong core. This becomes vital when the goal is high-level athletic performance since, without adequate core strength and stability of the lumbar spine, the athlete will not be able to apply properly extremity strength\(^10\). (Akhuthota V, 2004). (Hedrick, 2000)\(^11\)

Stability of the lumbar spine requires both passive stiffness, through the osseous and ligamentous structures, and active stiffness, through muscles. Spinal instability occurs when either of these components is disturbed. The effect becomes particularly important in overhead athletes because that stability acts as a torque-counter torque of diagonally related muscles during throwing (Akhuthota V, 2004)\(^8\).

A strong core is critical because the force is transferred most efficiently through the body in a straight line. When the trunk is poorly developed, the result is poor posture, which can lead to less efficient

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\(^{10}\) Akhuthota V, Nadur S F, Core strengthening 2004 (Archive of Physical medicine & rehabilitation 86-92)

\(^{11}\) Hedrick, Training of trunk for improved athletic performance (Strength and conditioning journal 2000, p 50-61)
movements. Such athletes will not be able to maximize their counter torque, often dissipating energy through jerky uncoordinated movement. (Hedrick, 2000)\textsuperscript{11}.

The core muscles should be approached as a three-dimensional system, concerned with support, the anticipation of unexpected loads, and to ensuring sufficient stiffness in any degree of freedom of the joint. Motor control activation and endurance are essential to achieving core stability under all possible conditions for performance and injury avoidance. The importance of coordinated muscle activity in athletic function cannot be underestimated. (McGill SM, 2003)\textsuperscript{12}.

Core muscle strength and endurance is a key contributor to the stability of the lumbar spine (Panjabi, 1992, Jull and Richardson 2000, Arakoski 2001, McGill 2003, Akuthota 2004). Furthermore, the literature suggests that lumbar stability has an effect on an individual’s bowling performance (Young JL, 1996).\textsuperscript{13}

In addition Bartlett et al., (1996) suggested that studies were needed to establish a relationship between segmental dynamics, in

\textsuperscript{12} McGil S.M., Grenier S, Kavec N, Cholewicki J “ Condition of Muscle activity to assure stability of lumbar spine” (Journal of electromyography and kinesiology 2003, P. 353-359)
particular between muscle strength of the lower back and core region and bowling performance and incidence of injury. This study therefore seeks to establish whether a relationship exists between core stability and bowling performance and back injury. (Bartlett RM, 1996)\textsuperscript{14}

A well-developed core is vital when the goal is high-level athletic performance as all movements either originate or are coupled through the trunk (Hedrick, 2000)\textsuperscript{15}. A well-developed core allows for improved force output, increased neuromuscular efficiency and the decreased incidence of overuse injuries. It also enhances an athlete’s ability to utilize the musculature of the upper and lower body, which allows for more efficient, accurate and robust movements. This is because the force is transferred most efficiently through the body in a straight line. An athlete with a poorly developed core as well as poor posture will not be able to utilize fully their bodies potential power, often wasting energy through jerky, uncoordinated and extraneous movements.

If the lumbar muscular component has not been trained to function optimally, this can lead to weakness and reduced movement capabilities. Over time, this can lead to impaired athletic performance, injury and pain.

\textsuperscript{15} Hedrik, Training the trunk for improved athletic performance (Journal of strength and conditioning 2000, p. 50-61)
Motion is not an isolated event that occurs in one direction. A body movement is a complex activity involving agonist and antagonist structures that work together to create motion and to stabilize the body in all three directional planes. Hence an athlete’s core must be strong, flexible and unimpeded in its movement in order to achieve maximum performance (Abelson, 2004).

A conceptual & detailed biomechanical explanation is required to know about the primary stabilizing method of the human spine. Several models for the stabilizing system have been proposed by several researchers among that a well-excepted model was given by Panjabi. according to that spinal stabilization consist of three main systems. (Panjabi, 1992)

1. The Active system- all muscles & tendons surrounding the spinal column that can apply forces to spinal column consist the active system i.e. lumbar multifidus .
2. Passive system – The vertebrae intervertebral disc, and ligaments.
3. Neural system – The nerves & CNS
The proper function of stabilizing system is to provide sufficient stability to the spine to match with the varying stability demand due to changes in spinal posture and static & dynamic forces/load.

Muscles can be broadly divided into two categories, local and global muscles (Bergmark, 1989). The local muscle system includes deep muscles that are attached to the lumbar vertebrae and are capable of directly controlling the stiffness of the lumbar segment. In contrast, the global muscle system encompasses larger and more superficial muscles of the trunk. Their role is to move the spine and to control larger external loads, which occur with normal daily functions.

Biomechanical research has demonstrated that deep, local muscles are essential for controlling, protecting and supporting the joints. The muscles of local synergy, which are important for the lumbo-pelvic region, include the segmental lumbar multifidus, the transverse abdominis, the pelvic floor and the diaphragm.

For the lumbar region, it has been proposed that the multifidus can contribute to stability via control of lordosis, allowing equal distribution of forces (Aspden, 1992). Contraction of poly segmental multifidus

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18 Bergmark, Stability of the lumbar spine, A study in mechanical engineering (Acta orthop scand suppl, p.1-54)
fascicle can restore the lumbar lordosis. Recent studies have confirmed this finding, the compressive load bearing capacity of the passive thoraco-lumbar spine was significantly enhanced by pelvic rotation caused by minimal muscle forces in the sagittal plane (Keifer et al). When local muscles were examined in the model multifidus was found to contribute 80% of required activity (Keifer et al 1998). To maintain the spinal curves require a balance between & integration of local, monoarticular & global muscles (Kiefer A, 1997)\textsuperscript{19}.

A more clinical relevant description of this segmental stabilization theory & evidence to support the differing function of local versus global musculature has been presented by O’Sullivan et al. They describe the function local musculature (lumbar multifidus) as one of stabilizer of the lumbar spine with little respect to the movement direction, magnitude or velocity. Local stabilizing musculature activation occurs automatically in a preparatory manner prior to movement. Failure of this preparatory stabilizing mechanism is identified as a primary cause of persistence low back pain. (O’Sullivan P, 1997)\textsuperscript{20}.

\textsuperscript{19} Kiefer A, Shirazi A, Parnianpour M. “Stability of the human spine in neutral postures” European spine journal.
Literature that developed from and is supportive of segmental stabilization model has generated following:-

1. The lumbar multifidus muscle function is to provide segmental stability & movement guidance between segments. Although lumbar multifidus has been identified as an opposite rotator & lumbar extensor in classic kinesiology. Its role as a segmental stabilizer has more recently been described. Research has shown it to be active during lumbar spine flexion as well, indicating its eccentric stabilizing effect.

2. Lumbar multifidus atrophy & dysfunction has been linked with various aspect of LBP. Lumbar multifidus atrophy-

   • Is present in up to 80% of the subject with LBP as measured by MRI scans.

   • Is selective to one lumbar segment & is ipsilateral to the painful side.

   • Is associated with failed back syndrome & demonstrated morphological changes as detected by biopsy studies.

   • Does not come to normal spontaneously after resolution of LBP.
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- Is associated with reoccurrence of LBP after one and three years following the acute episode.

- Can be accurately measured by (CSA) clinically utilizing Ultrasound imaging as compared to MRI scan.

- Can reversed to normal with selective therapeutic exercise intervention utilizing RTUS as bio feedback

### Biomechanics of Fast and Fast/Medium Bowling

Success in fast bowling is determined by a combination of many factors, one paramount variable being the speed at which the ball is released. A quick ball release speed reduces the time available for the batsmen to make correct decisions about the path of the ball, thus increasing the demands on the effectors mechanism responsible for executing the right shot (Bartlett RM, 1996)\(^21\).

For the purposes of this review, the action of bowling is divided into the four distinct stages:

- **Run-up,**
- **The pre-delivery stride,**
- **The delivery stride and**
- **The follow-through.**

Figure-1

Figure-2

(www.google.com/images/bowling action)
**Run-up:-**

This stage commences when the bowler walks or jogs over his approach marker, gradually increasing speed on his approach to the wicket, and ends as he leaps into the air at the start of the pre-delivery stride in preparation for the back foot to strike the ground, which marks the commencement of the delivery stride (Bartlett et al., 1996). Elliot and Foster (1984) considered that the run-up speed should be sufficient to produce as high a linear velocity of the body as possible for ball release, but also must allow the correct delivery technique to be adopted. They also demonstrated that due to considerable differences in modes of delivery and run-up speeds that the percentage contribution of the run-up to ball release speed will vary between bowlers. (Elliot BC, 1984)

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**Pre-delivery stride:-**

This stage separates the run-up from the delivery stride and begins, for a right-handed bowler, with a jump off the left foot and is completed as the bowler lands on the right or back foot. During this stride, with the shoulders pointing down the wicket, the right foot passes in front of the left with the right foot turning to land parallel to the bowling crease.

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data is available with regards the pre-delivery stride and ball release speeds, however, studies have shown that this stride is longer than an average stride (Bartlett RM, 1996). This is caused by the apparent necessity to decelerate in the final stride and was probably associated with the need to ‘gather’ for the final thrust. (Davis K, 1976) 

Figure-3

Phase 1: Pre Delivery Stride (PDS)
Phase 2: Mid bound (MB)
Phase 3: Back Foot Contact (BFC)
Phase 4: Front Foot Contact (FFC)
Phase 5: Ball Release (BR)
Phase 6: Follow Through (FT)

As this is considered the most technical stage of the bowling action, the delivery stride will be outlined according to three key events: the back foot strike, front foot strike and ball release (Bartlett et al., 1996).

**Back foot strike**

At the start of the delivery stride, the bowler’s weight is on the previously planted back foot with the body leaning away from the batsman. According to Bartlett et al., 1996, this leaning back of the trunk may serve the purpose of increasing the acceleration path of the implement ball.

**Figure-4 Pre-delivery stride**
As the delivery stride proceeds, the front foot strikes the ground. The values for peak vertical impact force from previous force-platform studies has been found to be between 3.8 and 6.4 times body weight with anterior-posterior braking forces around two times body weight (Bartlett et al., 1996). Implications of this have mostly been recorded in terms of injury potential, with few relationships to ball release speed or the bowling technique being reported.
The laws of cricket limit the action of the bowling arm to circumduction of the upper arm about the glenohumeral joint and the extension and flexion of the wrist and finger joints (though it is recognised that the wrist could also abduct and adduct, the radio-ulnar joints could supinate/pronate and the carpal joints can move) [Bartlett et al., 1996]. The circumduction of the upper arm with the elbow either fully extended or at least a constant angle starts from a position close to
the hip joint. Initiation of upper arm circumduction usually occurs between back foot and front foot strikes. The literature suggests that the degree of circumduction between front foot strike and ball release varies and that it is dependent not only on the position of the arm at release, but also on its position as the front foot lands (Bartlett et al., 1996).

![Figure-7 Ball release](image)

**Follow-through:-**

Limited data is available on the follow-through, as most analyses stop shortly after ball release. It was suggested by Bartlett *et al.*, (1996) that the bowler should ensure that the bowling arm follows through down the outside of the left thigh allowing a gradual reduction in the bowlers speed and that the first stride of the follow-through should be behind the line of the ball, before running off the wicket for a further 2-3 strides.
Concept of core stability

Core stability is in essence “a description of the muscular control required around the lumbar spine to maintain functional stability” (Akhuthota V, Core strengthening, 2004)\textsuperscript{24}. (Wisbey-Roth, Grading and progressing a dysfunction specific core stability program, 1996)\textsuperscript{25}. Defined core stability as the optimal alignment and control of the spine and pelvis region to ensure efficient transfer of momentum and summation of forces across the segment, resulting in greater precision and safety of dynamic activity. (Wisbey-Roth, 1996) Core stability results

\textsuperscript{24} Akhuthota V, Nadur S F, Core strengthening 2004 (Archive of Physical medicine & rehabilitation 86-92)

\textsuperscript{25} Wisbey Roth T. Grading and progressing a dysfunction specific core stability program 1996
from highly coordinated muscle activation patterns involving many muscles, which provide support and control of the joints, and that the recruitment patterns must continually change, depending on the task. (Jull G, 1993)

According to the Lee (2001) model of integrated joint function, adequate approximation of the joint surfaces must be the result of all forces acting across the joint if stability is to be insured. Consequently, the ability to effectively transfer load through joints is dynamic and requires integrated functioning of the body’s neuromusculoskeletal system.

The first component, firm closure comprises intact bones, joints and ligaments. In a stable joint with closely fitting articular surfaces no extra forces are needed to maintain the state of the system, given the actual load situation (Lee, 2001). To analyze stiffness the zones of motion available to every joint must be considered including, the neutral and the elastic zone’s. The neutral zone is a small range of movement near the joint’s neutral position where minimal resistance is given by the osteo ligamentous structures. The elastic zone is the part of the motion from the

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end of the neutral zone up to the physiological limit. The size of the neutral zone may increase with injury, articular degeneration and/or weakness of the stabilizing musculature (Panjabi, 1992).

The second component according to Lee (2001) is called force closure and relies on the optimal function of the muscles which includes the ability to contract tonically in a sustained manner. Force closure reduces the size of the neutral zone and thus there is control between the two joint surfaces. Several ligaments, muscles and fascial systems contribute to the force closure of the pelvis. The inner unit consists of the muscles of the pelvic floor, TA, multifidus and the diaphragm also known as the local stabilizers. The outer unit consists of several slings or systems of muscles (global stabilizers and mobilizers) that are anatomically connected and functionally related. When muscles contract, they produce a force that spreads beyond the origin and insertion of the active muscle. This force is transmitted to the muscles, tendons, fascia, ligaments, capsules and bones that lie both in series and in parallel to the active muscle. In this manner, forces are produced quite distant from the origin of the initial muscle contraction.
The third component, motor control, is the ability of the muscles to perform in a co-ordinated manner such that the resultant force is adequate compression through the articular structures at an optimal point (tailored), in other words the timing of specific muscle action and release. Superb motor skills require co-ordination of muscle activity such that stability is ensured, and loads are transferred effortlessly. The last component is that of neural control (emotions and awareness), which ultimately orchestrates the pattern of motor control. This requires constant accurate afferent input from the mechanoreceptors in the joint and surrounding soft tissues, appropriate interpretation of the afferent input and a suitable motor response (Lee, 2001).

The lumbar multifidus (LM) and TA muscles, in particular have been shown to have the greatest contribution to the control of the neutral zone (Panjabi, 1992 and Richardson, 1995). (HJ Wilke, 1995) In a biomechanical study demonstrated that the LM provided more than two-thirds of the stiffness increase at the L4-L5 segment. Results of a study by Hodges (2003) indicate that elevated intra-abdominal pressure and contraction of the diaphragm and TA provide a mechanical contribution to the control of spinal intervertebral stiffness or stabilization particularly with regards to the drawing in of the abdominal wall. (P Hodges, 2003)
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Literature suggests that optimal core muscle strength, control and endurance working synergistically with the rest of the neuro-musculoskeletal system are necessary for lumbar spine stability (Panjabi, 1992, Jull and Richardson, 2000, Arakoski, 2001, Lee, 2001, McGill, 2003, Akuthota, 2004). Further literature suggests that lumbar stability has an effect on bowling speed (Young et al., 1996). Besides Bartlett et al., (1996) suggests that studies are needed to establish a relationship between segmental dynamics and bowling speed. This study, therefore seeks to establish whether a relationship exists between core stability and bowling speed.

The importance of muscular system in stabilizing the lumbar spine cannot be underestimated, a point well illustrated by the recent study that support quantitative data on the stabilizing effects of muscles on the mechanics of the spine.

Delimitation

1. This study was delimited to the male fast bowlers who were playing competitive cricket.

2. This study was further delimited to bowling speed, throwing capacity, prone hold test, core strength and incidence of back pain.

3. This study was delimited to the bowlers of age group 16-21 years.
Introduction

Limitation

1. For male bowler’s factors like daily routine, lifestyle, weight, height, bowling pattern etc. which might affect the study is considered as the limitation of study.

2. Regarding back pain only player’s response is considered as a limitation of the study.

3. This study was limited to the club / district level bowlers.

4. This study was confined to the small sample size.

Significance of study

1. It may bring to light the contribution of core stability training on the performance of fast bowlers.

2. Finding might help the coaches and players to constitute or modify the training programs for the bowlers to enhance the performance.

3. It may contribute to helping in avoiding the incidence of low back pain in bowlers.

4. The finding of the study may give the basic guideline to coaches and players to formulate effective training program for the various type of bowlers.
5. We would be able to inform athletes of a correct and necessary training program for their core stabilizers, thus reducing the possibility of injury and increasing the level of their performance and duration of their sports career.

**Need for study**

The factors that affect lumbar stability have been an area of extensive research. The clinical application of this research in the form of lumbar stabilization exercise programs:-

1. Will be useful as a common treatment of low back pain in fast bowlers.
2. Will also be useful for athletes to improve performance and
3. Will be helpful for the general public to prevent injuries and promote health

**Aims of the study**

The aim of this study is to establish a relationship between core muscle and its effect on the performance of the fast bowlers in cricket.

1. To determine the relationship between core strength and bowling speed.
2. To determine the relationship between core strength and throwing capacity.

3. This study will be helpful in establishing a baseline data about how the core muscle strength will affect the performance in term of throwing capacity, bowling speed and accuracy of the fast bowlers.

4. This study will also be useful in determining the effect of core stability exercise in the prevention of the low back injuries in the fast bowlers.

5. This study will also be useful in determining the effect of core stability exercise on the endurance of core muscles.

**Hypotheses:-**

1. There will be a significant increase in bowling speed in bowlers with core stability training.

2. There will be a significant improvement in the throwing power of the fast bowlers with core stability exercises.

3. There will be a significant increase in the strength of core muscles with core stability exercises.

4. There will be significant decrease incidences of low back pain among the bowlers who underwent core stability training.

5. There will be a significant improvement in prone hold among the fast bowlers with core stability training.
Sincere, honest and scholarly efforts have been made by the research scholar to study the relevant literature and research work pertaining to the present study. A study of relevant literature is an essential step for getting the full picture of what has been done and said concerning to the problem under study. This reviews the relevant available literature and includes a description of the anatomy of the core muscles, the biomechanics of fast bowling action particularly related to ball velocity, the concept of core stability and the relationship between core stability and bowling speed and also with incidence of back pain. The literature review provides a greater understanding of the problems and its crucial aspects and ensures the avoidance of unnecessary duplication. It also provides a comparative data on the basis of which evaluation and interpretation were made to reach at the significance of the findings. The relevant study selected from various sources, which the researcher has come across and which are of direct or indirect relevance to the present study, are cited below.

According to Marshall and Murphy (2005)\textsuperscript{27}, core stability is a generic description for the training of the abdominal and lumbopelvic region. To

\textsuperscript{27} Marshall, Paul W., and Bernadette A. Murphy. “Core stability exercises on and off a Swiss ball.” Archives of physical medicine and rehabilitation 86, no. 2 (2005): 242-249.
define core stability, the combination of a global and local stability system has been used. The global system refers to the larger superficial muscles around the abdominal and lumbar region; such as the rectus abdominus, paraspinal and external obliques. These muscles are the prime movers for trunk or hip flexion, extension or rotation. Unlike the local muscles, the global muscles are important for torque production and general trunk stability because they are not directly attached to the spine (Stevens et al. 2006).

Local stability refers to the deep intrinsic muscles of the abdominal wall, such as transverse abdominus, and multifidus. These muscles are associated with segmental stability of the lumbar spine during gross whole body movements (Marshall and Murphy, 2005).

According to Stevens et al. (2006)\(^\text{28}\), local muscles of the trunk, such as transverse abdominus and multifidus, with their vertebra to vertebra attachments, are supposed to control the fine tuning of the positions of adjacent vertebra (segmental stabilization). Because of their connection through the thoraco-lumbar fascia, the transverse abdominus and the internal oblique, have direct attachment to the lumbar vertebra; thus, are considered to be local muscles. Combining these two concepts of local

and global stability, it has been proposed that the alterations in the control of these muscles may lead to dysfunction of the deep/local muscle groups and consequently contribute to segmental spinal instability (Beith et al. 2001). According to O’Sullivan (2005), coordinated patterns of muscle recruitment are essential between the global and local muscle system of the trunk, in order to compensate for the changing demands of daily life, to ensure that the dynamic stability of the spine is preserved.

According to Lee and Vleeming (2003)\textsuperscript{29}, there are significant neurophysiological differences in timing of contraction of these two muscle systems. When loads are predictable, the local system contracts prior to anticipation of the movement, regardless of the direction, whereas the global system contracts later and is direction dependent. Research is still lacking in classifying all muscles into the two different muscle systems and clinically it appears that parts of some muscles may belong to both systems.

The function of the local muscle system, according to Lee and Vleeming (2003), is to stabilize the joints of the spine and pelvic girdle in preparation or in response to external loads. This can be achieved through several mechanisms; increase in intra-abdominal pressure, increase in

tension of the thoracodorsal fascia and increase in the articular stiffness. Research has shown that when the central nervous system can predict the timing of the load, the local system is anticipatory when functioning optimally. Therefore, these muscles work at low levels at all times and increase their action before any further loading or motion occurs. When the local muscle system is functioning optimally, it provides anticipatory inter segmental stiffness of the joints of the lumbar spine and pelvis. The external force, which Lee and Vleeming (2003) termed force closure, augments the form closure (shape of the joints) and helps prevent excessive shearing at the times of loading. This compression occurs prior to the onset of any movement and prepares the low back and pelvis for additional loading from the global system.

Lee and Vleeming (2003) state that a muscle contraction produces a force that spreads beyond the origin and insertion of the active muscle. This force is transmitted to other muscle tendons, fascia, ligaments, capsules and bones that lay both in series and parallel to the active muscle. Therefore, in this manner, forces are produced quite a distance from the origin of the initial muscle contraction.

Stability and movement are critically dependent on the coordination of all these muscles surrounding the lumbar spine. Although
recent research has advocated the importance of a few muscles, in particular transverse abdominus and multifidus, all core musculature are needed for optimal stabilization and performance (Akuthola and Nadler, 2004).

According to the Lee (2001)\textsuperscript{30} model of integrated joint function, adequate approximation of the joint surfaces must be the result of all forces acting across the joint if stability is to be insured. Consequently, the ability to effectively transfer load through joints is dynamic and requires integrated functioning of the body’s neuro-musculoskeletal system.

The first component, firm closure comprises intact bones, joints and ligaments. In a stable joint with closely fitting articular surfaces no extra forces are needed to maintain the state of the system, given the actual load situation (Lee, 2001). To analyze stiffness the zones of motion available to every joint must be considered including, the neutral and the elastic zone’s. The neutral zone is a small range of movement near the joint’s neutral position where minimal resistance is given by the osteo-ligamentous structures. The elastic zone is the part of the motion from the end of the neutral zone up to the physiological limit. The size of the

\textsuperscript{30} Lee D., “An integral model of joint function and its clinical application. Presentation at the 4\textsuperscript{th} interdisciplinary world congress on low back pain and pelvic pain”, Montreal.
neutral zone may increase with injury, articular degeneration and/or weakness of the stabilizing musculature (Panjabi, 1992). The second component according to Lee (2001) is called force closure and relies on optimal function of the muscles which includes the ability to contract tonically in a sustained manner. Force closure reduces the size of the neutral zone and thus heat is controlled between the two joint surfaces. Several ligaments, muscles and fascial systems contribute to force closure of the pelvis. The inner unit consists of the muscles of the pelvic floor, TA, multifidus and the diaphragm also known as the local stabilizers. The outer unit consists of several slings or systems of muscles (global stabilizers and mobilizers) that are anatomically connected and functionally related. When muscles contract, they produce a force that spreads beyond the origin and insertion of the active muscle. This force is transmitted to the muscles, tendons, fascia, ligaments, capsules and bones that lie both in series and in parallel to the active muscle. In this manner, forces are produced quite distant from the origin of the initial muscle contraction.

The third component, motor control, is the ability of the muscles to perform in a co-ordinated manner such that the resultant force is adequate

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compression through the articular structures at an optimal point (tailored), in other words the timing of specific muscle action and release. Superb motor skills require co-ordination of muscle action such that stability is ensured and loads are transferred effortlessly. The last component is that of neural control (emotions and awareness), which ultimately orchestrates the pattern of motor control. This requires constant accurate afferent input from the mechanoreceptors in the joint and surrounding soft tissues, appropriate interpretation of the afferent input and a suitable motor response (Lee, 2001).

The lumbar multifidus (LM) and TA muscles in particular have been shown to have the greatest contribution to the control of the neutral zone (Panjabi, 1992 and Richardson, 1995). (HJ Wilke, 1995) in a biomechanical study demonstrated that the LM provided more than two thirds of the stiffness increase at the L4-L5 segment. Results of a study by Hodges (2003) indicate that elevated intra-abdominal pressure and contraction of the diaphragm and TA provide a mechanical contribution to the control of spinal intervertebral stiffness or stabilization particularly with regards to the drawing in of the abdominal wall. (P Hodges, 2003)
Cholewicki et al. (1997)\(^{32}\) demonstrated that modest levels of coactivation of the paraspinal and abdominal wall muscles were necessary to maintain a stable spine in a neutral position. Continuous, low grade muscle activation of these muscles should maintain stability with all activities of daily living. Studies by Luoto et al (1995) suggested that it is not absolute strength of the local stabilising muscles that prevents injury or lumbo-pelvic dysfunction but endurance capacity or muscle control.


**R.M. Bartlett, N.P. Stockill, B.C. Elliott And A.F. Burnett (1996)\(^{33}\)** Did a study on “The Biomechanics of fast bowling in men's


This review concentrates on synthesizing and analyzing the biomechanical research which has been carried out on fast bowling in men's cricket. Specifically, it relates to those elements of the bowling technique which contribute towards a fast ball release, the aerodynamics and technique of swing bowling, and the association between fast bowling and lower back injury. With regard to bowling technique, no firm conclusions are drawn on the relationships between elements of the fast bowling technique and ball release speed. Recommendations for future research in this area include intra-player studies to establish the bowler-specific factors which contribute to fast ball release and features of body segment dynamics. There is general agreement that the phenomenon of differential boundary layer separation is the reason for normal and reverse cricket ball swing.

Systematic research to establish the essential aspects of the bowling technique which contribute to successful swing bowling is recommended, along with studies of the behavior of the ball in games to ascertain the effects of ball asymmetries on ball swing. There is sufficient evidence in the literature to establish a strong link between injury to the lower back and the use of the mixed technique. Recommendations are made for screening and intervention to reduce the use of the mixed
technique, and for research into other aspects of injury. Fundamental research to develop biomechanical models of the lower back in fast bowling is strongly recommended.

A.F. Burnett, C.J. Barrett, R.N. Marshall, B.C. Elliott, R.E. Day (1998)\(^{34}\), did a study on, “Three-dimensional measurement of lumbar spine kinematics for fast bowlers in cricket”, to determine whether the three-dimensional (3-D) lumbar spine kinematics for the mixed fast bowling technique differed to those of the side-on and front-on fast bowling techniques. No significant differences (P<0.004) existed between the side-on/front-on and mixed groups for 12 selected variables derived from the lumbar spine kinematic data. However, an examination of effect sizes revealed evidence that the mixed group showed: a greater amount of left lateral bend and an extended lumbar spine at front foot impact; a body position further from a neutral orientation at release; and a greater range of motion and angular velocity of the trunk in the lateral bending and flexion extension axes. Selected lumbar range of motion and velocity measures tended to be higher for mixed bowlers than side-on/front-on bowlers.

Akuthota, V., A. Ferreiro, T. Moore, And M. Fredericson\textsuperscript{35}. In “Core Stability exercise principles” found that, Core stability is essential for proper load balance within the spine, pelvis, and kinetic chain. The so-called core is the group of trunk muscles that surround the spine and abdominal viscera. Abdominal, gluteal, hip girdle, paraspinal, and other muscles work in concert to provide spinal stability. Core stability and its motor control have been shown to be imperative for initiation of functional limb movements, as needed in athletics. Sports medicine practitioners use core strengthening techniques to improve performance and prevent injury. Core strengthening, often called lumbar stabilization, and also has been used as a therapeutic exercise treatment regimen for low back pain conditions. This article summarizes the anatomy of the core, the progression of core strengthening, the available evidence for its theoretical construct, and its efficacy in musculoskeletal conditions.

**Bruce Kevin Hilligan (2008)\textsuperscript{36}** did a study on “The Relationship between Core Stability and Bowling Speed in Asymptomatic Male Indoor Action Cricket Bowlers.” When comparing the core stability factors (initiation of contraction; timed contraction; core strength parameters;


\textsuperscript{36} Hilligan, Bruce Kevin. "The relationship between core stability and bowling speed in asymptomatic male indoor action cricket bowlers." PhD diss., 2008.
lumbar pelvic stability) between the two groups (inter-group analysis) it was expected that these factors would differ between the two groups since a combination of these factors were the determinants of the grouping system. There was no significant difference in the fluctuation (in mmHg) away from 70mmHg between the two groups ($p = 0.308$). However, the difference (in mmHg) and the time (in seconds) for which an individual could maintain the contraction were significantly different between the groups, the latter being highly significant ($p = 0.047; p < 0.001$). There were significant differences in the grades (1a, 1b, 2a and 2b) between the groups when testing lumbar pelvic stability in terms of both the sagittal and rotation tests ($p = 0.006; p = 0.004; p < 0.001; p < 0.001$). There was a highly significant difference in bowling speed between the two groups ($p<0.001$), with Group A (117.3 ± 7.14 km.h-1) bowling significantly faster than group B (101.6 ± 3.76 km.h-1).

The group with well-developed core stability bowled significantly faster than the group with poorly-developed core stability. This suggests that well-developed core stability has a positive effect on bowling speed. Marc R. Portus, Peter J. Sinclair, Stephen T. Burke, David J.A. Moore And Patrick J. Farhart (2000) did a study on Cricket fast bowling
performance and technique and the influence of selected physical factors during an 8-over spell.

The aims of this study were to determine the influence of an 8-over spell on cricket fast bowling technique and performance (speed and accuracy), and to establish the relationship of selected physical capacities with technique and performance during an 8-over spell. Fourteen first-grade fast bowlers with a mean age of 23 years participated in the study. Physical capacities assessed were abdominal strength, trunk stability, selected girth and skin fold measures. During the delivery stride, bowlers were filmed from an overhead and lateral perspective (50 Hz) to obtain two-dimensional data for transverse plane shoulder alignment and sagittal plane knee joint angle respectively. Ball speed was measured by a radar gun and accuracy by the impact point of each delivery on a zoned scoring target at the batter’s stumps. Shoulder counter-rotation did not change significantly between over 2 and 8 for all bowlers, but was significantly related to a more front-on shoulder orientation at back foot impact. When the front-on fast bowlers \((n = 5)\) were isolated for analysis, shoulder counter-rotation increased significantly between over 2 and 8. Ball speed remained constant while accuracy showed some non-significant variation during the spell. Shoulder counter-rotation was significantly related to
accuracy scores during the second half of the 8-over spell. Chest girth and composition and body composition were significantly related to ball release speed at various times during the spell.

**Lloyd Clarke (2009)** did “A comparison study between core stability and trunk extensor endurance training in the management of acute low back pain in field hockey players.” The results of this study found that the Trunk Extensor Endurance Group, that performed the trunk extensor endurance training program, yielded better results in core stability and trunk extensor endurance. However, the Core Stability Group, that performed the core stability training program, showed a quicker reduction in pain levels during the three week intervention period. Therefore, by combining both training programs, future rehabilitation of athletes suffering from acute low back pain will be more successful. Sport performance of the athletes (field hockey players), through the proponents of Swiss ball training, will also improve.

**Kimberly M. Samson**, did a study on “The Effects of a Five-Week Core Stabilization-Training Program on Dynamic Balance in Tennis Athletes” and found that Core stabilization and dynamic balance

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are important components to the sport of tennis. The purpose of this study was to assess the outcome of a five-week core stabilization training program on dynamic balance. The study was a 2x2 factorial design with an experimental and control group. This study included 13 healthy physically active collegiate level tennis athletes and 15 subjects in the control group of aged matched activity cohorts. The five-week protocol for the core stabilization-training program was conducted as follows: subjects followed the program 3 times a week for an average of 30-minute sessions. There were 3 progressive levels of exercises focusing on strengthening the core while maintaining neuromuscular control. All subjects chosen for the study completed a pre and post-test measurement of their dynamic balance using the Star Excursion Balance Test (SEBT). The test was conducted one week prior to and following the five-week exercise protocol. No significant difference was found for pre-test results for all excursions. A significant difference for time was found for pre-test and post-test within subjects for all eight excursions (anterior, antero-medial, medial, postero-medial, posterior, postero-lateral, lateral, antero-lateral). There were no significant main effects for Group or interaction between Time and Group. In conclusion, Core stabilization-training may be used to enhance dynamic balance in tennis athletes.
Warren B. Young (2006)³⁹ did a study on “Transfer of Strength and Power Training to Sports Performance”. The purposes of this review are to identify the factors that contribute to the transference of strength and power training to sports performance and to provide resistance-training guidelines. Using sprinting performance as an example, exercises involving bilateral contractions of the leg muscles resulting in vertical movement, such as squats and jump squats, have minimal transfer to performance. However, plyometric training, including unilateral exercises and horizontal movement of the whole body, elicits significant increases in sprint acceleration performance, thus highlighting the importance of movement pattern and contraction velocity specificity. Relatively large gains in power output in nonspecific movements (intramuscular coordination) can be accompanied by small changes in sprint performance. Research on neural adaptations to resistance training indicates that inter-muscular coordination is an important component in achieving transfer to sports skills. Although the specificity of resistance training is important, general strength training is potentially useful for the purposes of increasing body mass, decreasing the risk of soft-tissue injuries, and developing core stability. Hypertrophy and general power

exercises can enhance sports performance, but optimal transfer from training also requires a specific exercise program. Core stability is in essence “a description of the muscular control required around the lumbar spine to maintain functional stability” (Akuthota, 2004). Wisbey-Roth (1996) defined core stability as the optimal alignment and control of the spine and pelvis region to ensure efficient transfer of momentum and summation of forces across the segment, resulting in greater precision and safety of dynamic activity.

Shinkle J, Nesser TW, Demchak TJ, McMannus DM\textsuperscript{40} did study on “Effect of core strength on the measure of power in the extremities” found that core strength does have a significant effect on an athlete's ability to create and transfer forces to the extremities. The core is centre of most kinetic chains in the body and should be trained accordingly.

Kibler WB, Press J, Sciascia A.\textsuperscript{41} In “The role of core stability in athletic function.”

The importance of function of the central core of the body for stabilisation and force generation in all sports activities is being

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increasingly recognised. 'Core stability' is seen as being pivotal for efficient biomechanical function to maximise force generation and minimise joint loads in all types of activities ranging from running to throwing. 'Core stability' is defined as the ability to control the position and motion of the trunk over the pelvis to allow optimum production, transfer and control of force and motion to the terminal segment in integrated athletic activities. Core muscle activity is best understood as the pre-programmed integration of local, single-joint muscles and multi-joint muscles to provide stability and produce motion. This results in proximal stability for distal mobility, a proximal to distal patterning of generation of force, and the creation of interactive moments that move and protect distal joints.

Leetun DT, Ireland ML, Willson JD, Ballantyne BT, Davis IM. In “Core stability measures as risk factors for lower extremity injury in athletes” found that Decreased lumbo-pelvic (or core) stability has been suggested to contribute to the aetiology of lower extremity injuries, particularly in females. This prospective study compares core stability measures between genders and between athletes who reported an injury during their season versus those who did not.

Finally, we looked for one or a combination of these strength measures that could be used to identify athletes at risk for lower extremity injury.

Scott J Butcher, Bruce R. Craven et al (2007)\textsuperscript{43} did a study “The Effect of Trunk Stability training on vertical takeoff velocity.” They concluded that trunk stability training will provide a more stable pelvis and spine from which the leg muscle activated. Thus promoting optimal force production during sporting activities such as vertical jump.

Renee E. Zingaro in their study (2008)\textsuperscript{44} “A correlation between core strength & serve velocity in collegiate tennis players”, concluded that core strength does have a correlation to serve velocity in women. However the men, who did not have correlation between core strength and serve velocity, seem to produce most of their force from upper body strength. However this could have been altered by small male sample size. It has been previously stated that 54% of tennis serve speed comes from the trunk and lower extremities.


\textsuperscript{44} Zingaro, Renee E. \textit{A Correlation Between Core Strength and Serve Velocity in Collegiate Tennis Players}. ProQuest, 2008.
Chris sharrock, Jarrod Cropper et al (2011)\textsuperscript{45} did a pilot study of “core stability and athletic performance: is there a relationship?” with the objective to evaluate the relationship between core stability and athletic performance measure in male and female collegiate athletes. A sample of 35 volunteer student athletes participated. The study result shows that there appears to be a link between core stability test and athletic performance. However more research is needed to provide a definitive answer on the nature of relationship to core stability.

Young J.L., Hering S.A, Press J.M. (1996)\textsuperscript{46} in their study “The influence of the spine on the shoulder in the throwing athlete” described Analysis of shoulder dysfunction in throwing and overhead athletes can no longer be restricted to evaluation of the gleno humeral joint alone. The isolated shoulder is incapable of generating the force necessary to hurl a baseball at velocities of 90-100 miles per hour or serve a tennis ball in excess of 120 miles per hour. The purpose of this paper is to provide a literature based theoretical framework for the role of the spine during these activities. The spine is a pivotal component of the kinematic chain which functions as a transfer link between the lower and upper limbs, a


force generator capable of accelerating the arm, and a force attenuator which dampens shear forces at the gleno humeral joint during the deceleration phase of the pitching motion. Side bending and rotation of the cervical spine facilitates visual acquisition of the intended target. Inflexibility of the hip musculature and weakness of the muscles which attach to the thoraco lumbar fascia have profound effects upon spine function which secondarily places greater stress upon the gleno humeral joint and rotator cuff. Shoulder rehabilitation and injury prevention programs should include evaluation of and exercise regimens for the lumbar, thoracic and cervical spine.

Michael Fredericson & Tammara Moore (2005) in “Core stabilization training for middle and long distance runners” discussed the theory behind the core training for injury prevention and improving a distance runner’s efficiency and performance. For runner’s whose events involve balance and powerful movements of the body propelling itself forward and catching itself in complex motor patterns – a strong foundation of muscular balance is essential, in many runner, however even those at an Olympic level, the core musculature is not fully developed thus increasing the chance of injury.

Yuki Miyake, Ryuji Kobayashi, & Dolly Kelepecz (2012)\(^{48}\) in the study “Core exercises elevate trunk stability to facilitate skilled motor behavior of the upper extremity.” result shows that core exercises improved core stability for the upper extremities. It is believed that improving trunk stability produces distal stability and thus improves the controlled movement of upper extremities. Trunk stability ensured the movement of shoulders, and shoulder stability improved the movement of the elbow, wrist and finger.

Jae-Ho Yu, & Gyu-Chang Lee (2012)\(^{49}\) did a study “Effect of core Stability Training using pilates on lower extremity muscle strength and postural stability in healthy subjects.” To investigate the effect of core stability training using pilates for 8 weeks on lower extremity muscle strength and postural stability. The result of the study indicates that pilates core stability training enhances motor performance skill by increasing lower extremity strength and improving postural stability and can prevent musculoskeletal disorders and thus improve quality of life.


METHODOLOGY

Participants were selected/ recruited from the Cricket academy M.P. Cricket association Indore, C.C.I. cricket club Indore, University cricket team at university Vadodara, Cricket Academy Goa.

The participant’s evaluation & selection process began with all possible participants undergoing a cursory interview in order to exclude subjects that did not fit criteria for study. Selected participants were evaluated at a single evaluation during which each of them were given a letter of consent, brief introduction of the process, that explained them the study and allowed them to withdraw at any time from study. To confirm whether subject could participate in the study a brief medical history, history of LBP a physical examination was done.

Sampling procedure

Participants those fulfilled the exclusion and inclusion criteria were randomly divided into group A and group B 100 current fast bowlers were included into the study. After taking written consent and detailed assessment they were further divided into two groups.
**Group A** – Includes 50 current fast bowlers. After assessing initial parameters they will be given 8 weeks core stability training.

**Group B** – Were consisting of 50 fast bowlers. This group were following the general training protocol.

**Inclusion criteria**

Subjects were included in this study if:

1. They had no current episode of lower back pain and had to have been asymptomatic with regards lower back pain for three months or longer (Guerrero, 1999).

2. They were between the ages of 16 to 21 years.

3. They had been playing Action Cricket in one of the intermediate leagues for at least six months. Subjects were matched to subjects of similar experience and league standing.

4. They were male. Differences between male and female anatomy and physiology were taken into account, and it was therefore found to be favorable to focus exclusively on a specific gender to further maintain homogeneity.
Exclusion criteria

Subjects were excluded from this study if they:

1. Had any relative contra-indications to abdominal muscle strengthening:
   i. Glaucoma  ii) Hypertension  iii) Osteoporosis  iv) Spinal tumours  
   v) Impaired circulation (Harms-Ringhdal, 1993).

2. Had extreme discomfort on contracting the abdominal muscles.

3. Were spin bowlers.

4. Had any current injury to the kinematic chain that impaired their ability to bowl.
METHODOLOGY

Screened and included for study
n=100

Baseline Outcome Measures
1. Bowling Speed
2. Throwing Distance
3. Strength of Core Muscles
4. Prone Hold Test
5. Incidence of Back Pain

Randomized
n=100

Group A
Core Stability Training + General Training Protocol
n = 50

Group B
General Training Protocol
n = 50

8 Weeks Intervention

Post Intervention Evaluation
n=50

8 Weeks Intervention

Post Intervention Evaluation
n=50
Data

The following outcome measures will be considered for performance of fast bowlers.

1. **Bowling speed**- it is measured by the speed sensor ball and speed gun.

2. **Throwing capacity**- it is measured by making subject throw the ball and distance will be measured by **measuring tape**

3. **Strength of core muscles**- this is measured by **pressure feedback machine**

4. Back pain incidences of LBP during the study period

5. **Prone Hold Test**- this measured the endurance of core muscles.

Procedure

The first data collection tool was Sphygmomanometer, the pressure biofeedback unit (PBU). The PBU provide the numerical readings, which were used for purpose of statistical analysis. The PBU provides objective reading, which represented core stability muscle activation.
Mills (2005) states that lumbo pelvic instability is defined as deviation of the lumbar spine and pelvis from arbitrarily defined neutral position, and is demonstrated by change in the cuff pressure, which is indicated on the PBU.

Participant is asked to empty the bladder as the filled bladder hinders the performance of the core muscles. Subjects were then explained the contraction of core muscles before commencing with abdominal in drawing.

The subjects were in the supine crook lying position, the PBU was placed under the lumbar spine in order to identify movement of the lumbopelvic region. The PBU provided a measure of movement away from the neutral position; the PBU was inflated to 40 mm Hg. A core muscle contraction and posterior pelvic tilt was performed the difference in the PBU pressure is noted.
The test was demonstrated to the subjects and then they were requested to do a practice test to ensure that they understood the test. After 5 mins of the rest participant is asked to perform actual test and reading is noted.

After the break of 10 mins participants were explained to perform Prone Hold test and participant is asked to perform this maneuver. Duration for maintaining this position was noted this give endurance status of the core musculature.

Figure-9 Core stability
Then participants are asked to have warm up and after that they were asked to throw a ball without taking run-up and then this distance is measured by measuring tape, this distance will give us the fair idea regarding the throwing capacity of the participants.

Bowling speed was measured by Speed sensor ball and the hot wheels speed gun. Participants are asked to do bowling and net without batsman and the speed of bowling is measured by both the devices in kmph. Average of the 6 balls were taken on record as baseline data.

After taking the baseline data participants of Group A were given 8 weeks core stability training along with normal training protocol and
Group B continued following the normal training protocol. After 8 weeks all variables were measured.

Individuals were asked for the back pain incidence during the follow up. They are supposed to answer in yes / no.

All outcome measures were tested by an evaluator who is blinded to group allotment and was having good experience in making use of these outcome measures.

**Tools**

1. Sphygmomanometer/ Pressure biofeedback (PBU)
2. Speed Sensor Ball (Platypus)
3. Speed Gun (Hot Wheels)
4. Cricket ball
5. Measuring tape
6. Exercise Mat
7. Swiss Ball
8. Balance Board
9. Medicine Ball
10. Theraband
Figure- 11 Pressure bio-feedback unit

Figure-12 Speed Gun