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), core stability is a generic description for the training of the abdominal and lumbopelvic region. To define core stability, the combination of a global and local stability

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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)

According to Stevens et al. (2006)\(^2\), 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), 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

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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)⁴ 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 neutral zone may increase with injury, articular degeneration and/or weakness of the stabilizing musculature (Panjabi, 1992)⁵.

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⁴ Lee D., “An integral model of joint function and its clinical application. Presentation at the 4th interdisciplinary world congress on low back pain and pelvic pain, Montreal.
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 hear 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 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) 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

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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)7 Did a study on “The Biomechanics of fast bowling in men's cricket: A review” .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.

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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)\(^8\), 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. 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.

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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{10} 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; 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 ($p = 0.006; p = 0.004; p < 0.001; p <$

\textsuperscript{10} Hilligan, Bruce Kevin. “The relationship between core stability and bowling speed in asymptomatic male indoor action cricket bowlers.” PhD diss., 2008.
There was a highly significant difference in bowling speed between the two groups ($p<0.001$), with Group A ($117.3 \pm 7.14$ km.h$^{-1}$) bowling significantly faster than group B ($101.6 \pm 3.76$ 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.


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.

**Lloyed Clarke (2009)**\(^{11}\) 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

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REVIEW OF LITERATURE

successful. Sport performance of the athletes (field hockey players), through the proponents of Swiss ball training, will also improve.

Kimberly M. Samson\textsuperscript{12} 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 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

\textsuperscript{12} Samson, Kimberly M. “The effects of a five-week core stabilization-training program on dynamic balance in Tennis athletes.” PhD diss., West Virginia University, 2005.
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)\textsuperscript{13} 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 DM¹⁴ 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. 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 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

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(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{17} 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{18} “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{18} Zingaro, Renee E. A Correlation Between Core Strength and Serve Velocity in Collegiate Tennis Players. ProQuest, 2008.
Chris sharrock, Jarrod Cropper et al (2011)\textsuperscript{19} 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{20} 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)\textsuperscript{21} 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)\textsuperscript{22} 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)\textsuperscript{23} 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.

\textsuperscript{22} Miyake, Yuki, Ryuji Kobayashi, Dolly Kelepecz, and Masaaki Nakajima. "Core exercises elevate trunk stability to facilitate skilled motor behavior of the upper extremities." \textit{Journal of bodywork and movement therapies} 17, no. 2 (2013): 259-265.
