Original Article

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A Correlation between Latency Period of Transverse Abdominis and Dynamic Balance: An EMG Study

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Abstract

Introduction: Stabilizing the core is a dynamic process of maintaining balance. The Transverse abdominis (TrA) muscle is the first muscle activated during lower extremity movements indicating that it is primary muscle linked to core stability during lower limb movements. The literature in recent years has consistently linked the changes of the activity onset of the TrA as a marker of motor control dysfunction that directly reflects an impairment resulting in less than optimal mechanical stability of the lumbar spine This study evaluated the correlation between core stability and dynamic balance based on three objectives namely the myoelectrical activity of transverse abdominis and direction specific muscles of stance extremity (Vastus medialis ,Vastus lateralis and Biceps femoris) , the latency period of transverse abdominis and direction -specific muscles of stance extremity in respective directions of modified star excursion balance test and the Star Excursion Balance test (SEBT) score. The Research design is Experimental. 30 Healthy collegiate male from university were included in study based on inclusion criteria. The EMG electrodes were placed on Transverse abdominis, Vastus medialis obliques , Vastus lateralis , Biceps femoris muscles . The Ground electrode was placed on iliac crest . The Measurement was done through modified star excursion balance test score. The SEBT testing was done in anterior, posteromedial, posterolateral directions . the *SPSS 19.0* was used for statistical analysis. The level of significance $p<0.05$ was taken for all tests . the results showed Statistically significant, strong negative correlation between measure of core stability (latency period) and components of modified SEBT was found ($p<0.001$). **Conclusion:** The study found that latencies between transverse abdominis and direction specific muscle of SEBT to be highly correlated with each other, So it can be used as an objective assessment tool of core stability along with the modified SEBT score analysis.

Key words: SEBT; EMG; Transversus abdominis.

Introduction

Postural control or balance can be defined statically as ability to maintain a base of support with minimal movement and dynamically as the ability to perform a task while maintaining a stable position.[1] Control and maintenance of balance in upright posture is essential requirement for excelling in sports like soccer, basketball and gymnastics, as well as prevention from musculoskeletal injuries.[2]

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The ability to rapidly modulate the timing and recruitment of muscles in response to unexpected or expected postural perturbation is considered paramount in maintaining balance and posture.[3]

The central nervous system deals with stabilization of spine by contraction of abdominals and multifidus muscle in an anticipation of reactive forces produced by limb movements.[4] Anticipatory postural adjustments, determined by pre-programmed muscle activation, are involuntary and automatic adjustment to posture, occurring prior to focal muscle activity during limb movement. It is well accepted that CNS initiates sequence of muscle activity involving the limb and trunk muscles in advance of limb movements to prepare the body for predictable disturbance to stability from reactive forces caused by movement. This sequence of responses is called feed-forward, and occurs in advance of the limb movement.[4]

The control of spine equilibrium and mechanical stability requires appropriate muscle recruitment and timing.[5] One indicator of motor control for the lower back is timing or onset of abdominal muscle activation. The transverses abdominis (Tr.A) is the first muscle activated during lower extremity movements, indicating that it is the primary muscle linked to core stability during lower limb movements.[6]

Core muscle development is believed to be important in many functional and athletic activities, because core muscle recruitment should enhance core stability and help provide proximal stability to facilitate distal mobility. For optimal core stability, both the smaller, deeper core muscles and the larger, superficial core muscles must contract in sequence with appropriate timing and tension.[7]

Hodges and Richardson found the Transverse abdominis (TrA) to have delayed activation time in people with low back pain compared to healthy individuals, who had TrA activation before lower and upper limb movement. The activation of the TrA preceded the movements of the arms by 30 milliseconds, and the legs by 100 milliseconds, within the healthy individuals

While much of the literature has focused on differences in muscle activation level, timing and pattern of recruitment also play an important role in spine stability and movement control. Various relationships have been demonstrated between core stability, balance performance and activation characteristics of the trunk muscles. Most importantly, a significant correlation was found between poor balance performance in a sitting balance task and delayed firing of the trunk muscles during sudden perturbation. The Star Excursion Balance Test (SEBT) has been reported to train and assess dynamic balance and challenge athletes sufficiently.[8] The SEBT offers a simple, low-cost alternative to more sophisticated laboratory assessments for use in clinical settings.

The SEBT is a closed-kinetic chain exercise which mimics the single-leg squat exercise and therefore the stance leg requires strength, proprioception, neuromuscular control and adequate range of motion at the hip, knee and ankle joints.[8,9]

Earl and Hertel indicated that EMG activation of lower extremity muscles during the Star Excursion balance test was direction dependent[10], while others researchers have identified specific kinematic patterns that dictate performance of this task therefore providing clinicians with knowledge as to which directions are best suited for isolating particular muscles recruitment patterns in rehabilitation.

Present study is addressing motor control component of core stability and correlating it to dynamic balance.There has been dearth of literature studies correlating early onset muscle activation of transverse abdominis as a marker of core stability and dynamic balance at motor unit level.

Objective

The objectives of the study involve analyzing the myoelectrical activity of transverse abdominis and direction specific muscles of stance extremity (Vastus medialis,Vastus lateralis and Biceps femoris) and also to find out the latency period of transverse abdominis and direction-specific muscles of stance extremity in respective directions of modified star excursion balance test.The secondary objectives involve objective correlation of latency period and excursion in SEBT.

Methodology

The design of the study is corelational in nature. The sample population will be healthy collegiate male population. The Sample size was calculated based on previous researches, with level of significance α= 0.05, and 80% power. The sample size came out to be 30.

Inclusion criteria

a) Healthy collegiate male population
b) Age: 18-26 Years
c) BMI: 18.5 - 24.9
d) Normal AROM (unrestricted) of upper/ lower limb joints.
e) Single –leg stance ability >15 seconds

Exclusion criteria

a) Neurological symptoms in upper/lower quadrant
b) History/existence of fracture/dislocation in upper/lower quadrant

Figure1: Electrodes placement (a) Vastus medialis (b) Vastus lateralis (c) Biceps Femoris (d) Transverse abdominis

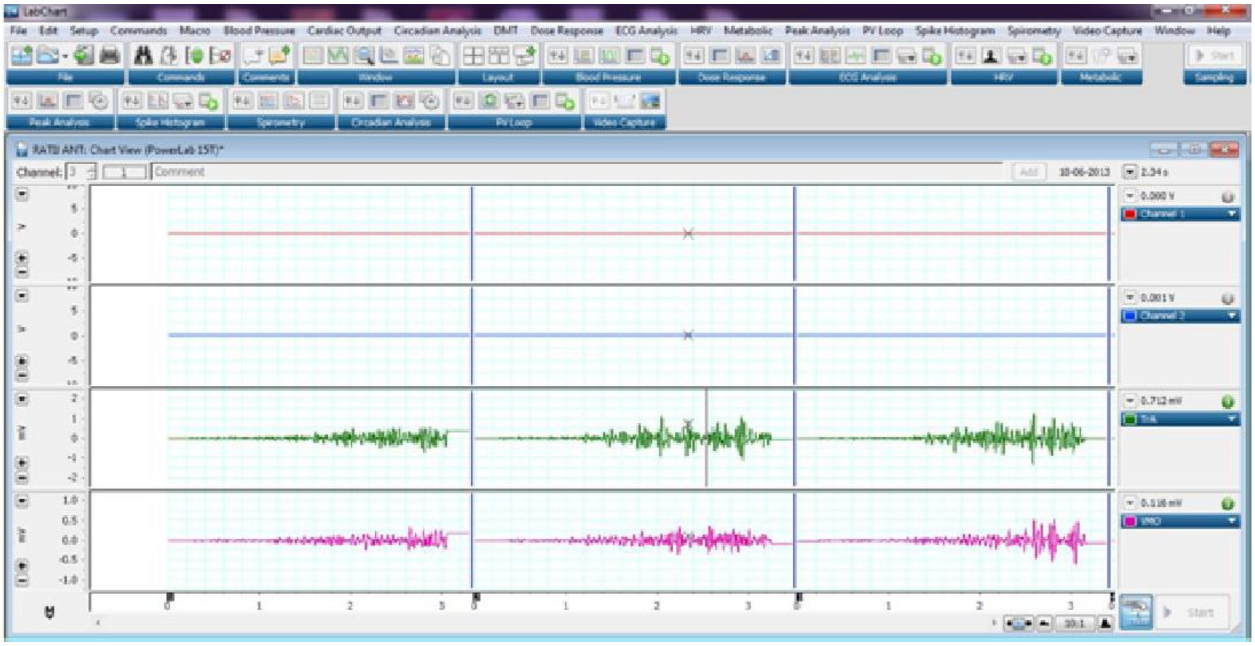
c) History/existence of any surgical procedures (ORIF/arthroscopy etc.) on extremity/spinal joints
d) History/presence of pathological condition in the back, shoulder, elbow, wrist etc.
e) History/presence of joint pain
f) History of abdominal surgery since last 2 years
g) Symptomatic low back pain
h) Presence of any vestibular, cerebellar or visual dysfunction that can affect balance.

Instrumentation

The instruments include:

Figure 2: Modified Dynamic Balance test (a) Anterior reach (b) Posterolateral (c) Posteromedial reaches

Figure 3: EMG showing latency between transverse abdominis and vastus medialis during anterior reach of modified SEBT



a) Modified SEBT instrument
b) AD instrument
c) Surface electrodes
d) Digital Stop watch
e) Digital Weighing scale
f) Stadiometer
g) Measuring tapes
h) Goniometer
i) Alcohol
j) Sand paper
k) Micro- pore tape

Procedure

Thirty subjects with no history of back and

Figure 4: EMG showing latency between transverse abdominis and biceps femoris during posterolateral reach of modified SEBT

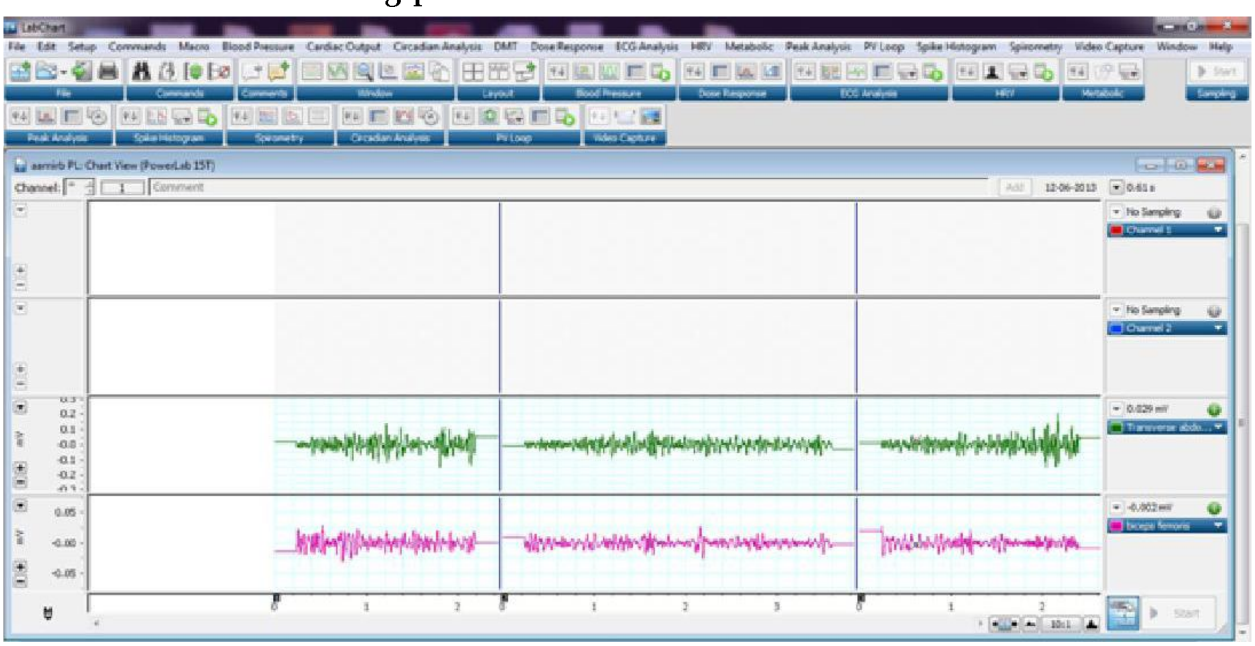
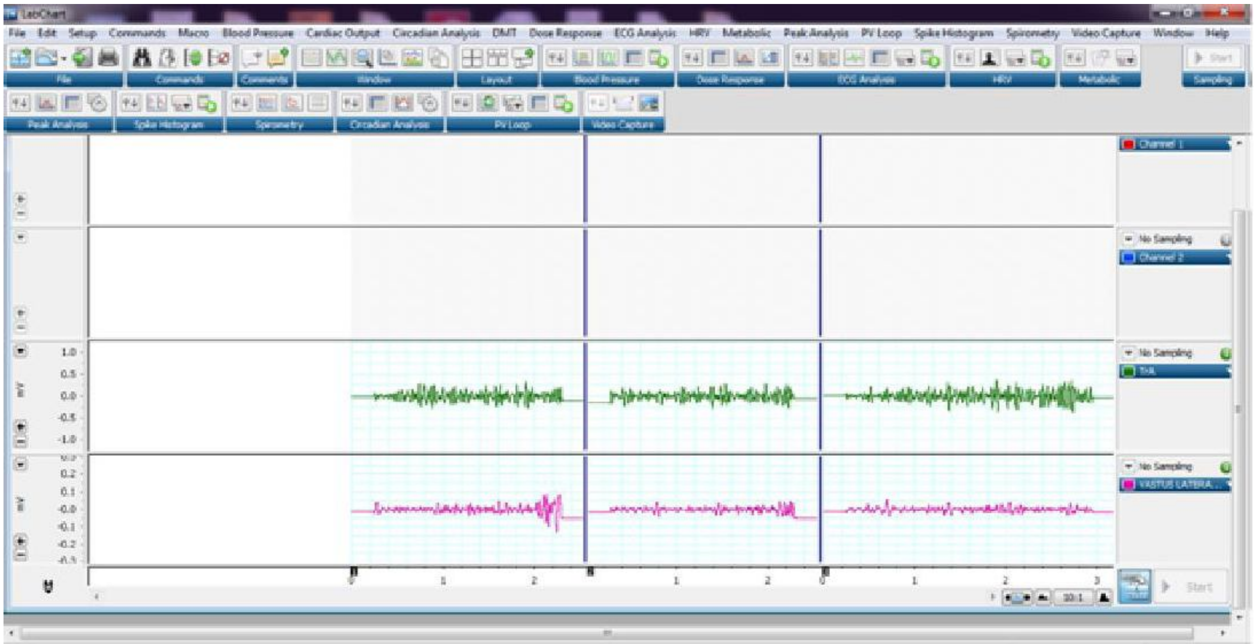


Figure 5: EMG showing latency between transverse abdominis and vastus lateralis during posteromedial reach of modified SEBT



shoulder pathology were included in the study. Each subject signed an informed consent after all the risks and benefits of the study were explained. Ethical approval for this study was obtained from Institutional Human Ethical Committee of Jamia Millia Islamia. A single subject's session would include the measurement of myo-electric activity (Surface EMG) and measurement of reach distance on Modified SEBT.

All EMG onsets were checked visually to ensure that they were valid and not interrupted by artifact from movement or the ECG. Pair of AgCl surface electrodes were used to record activity of transverse abdominis and direction specific muscles of stance 23 extremity i.e. vastus medialis oblique, vastus lateralis, and biceps femoris while performing modified star excursion balance test in anterior, postero-lateral and postero-medial directions respectively.

Electrodes placement

The electrodes were positioned parallel to the muscle fibers with an inter electrode distance of 20 mm following careful skin preparation to reduce the skin impedance. Electrodes placement for muscles will vary. [11]

Transverse abdominis: The electrodes for Transverse abdominis was placed 2 cm infero-medial to the ASIS, during performance of SEBT.

Vastus medialis obliques: Electrode for Vastus medialis oblique was placed on the muscle belly, 55O at an oblique angle, 2 cm medial from superior rim of patella, during performance of anterior excursion of modified SEBT.

Vastus lateralis: The electrodes for Vastus lateralis were placed 3-5 cm above patella at an oblique angle lateral to the midline during performance of posteromedial excursion of modified SEBT.

Biceps femoris: The electrode for biceps femoris was placed 2 cm apart parallel to muscle fibre on lateral aspect of thigh ,tho-third of distance between greater trochanter and back of the knee during performance of posterolateral excursion of modified SEBT.

Ground electrode: The ground electrode was placed on iliac crest.

EMG setting: EMG data were sampled at

Table 1: Descriptive analysis of entire group

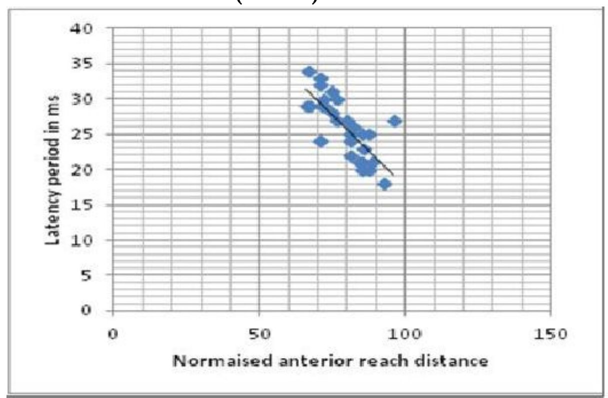
	N	Minimum	Maximum	Mean	Std. Deviation
Age (years)	30	18	25	21.46	2.22
Wt (kg)	30	46.3	75.0	59.41	7.09
Ht (metre)	30	1.50	1.80	1.68	0.070
BMI (kg/m^2)	30	17.86	25.78	21.16	2.29

Table 2: Correlation between latency period (LP) of transverse abdominis and vastus medialis with normalized anterior reach distance (NRA) of modified SEBT

		NRA	LP (ms)
NRA	Pearson Correlation coefficient	1	-.756**
	r value		.000
	N	30	30
LP (ms)	Pearson Correlation coefficient	-.756**	1
	r value	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 6: Scatter plot between latency period (LP) of transverse abdominis and vastus medialis with normalized anterior reach distance (NRA) of modified SEBT



1,000 Hz, band pass filtered between 20 and 1,000 Hz, and stored on computer for analysis (AD Instrument, Australia). Following data processing, the onsets of EMGs were identified visually as the point where the EMG activity exceeded the background level of activity. EMG onsets identified in this manner earlier have been compared with onsets using Matlab software values and found to be accurate.[12]

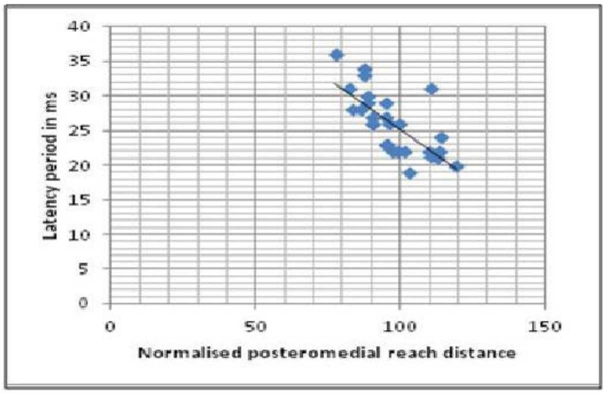
Measurement of modified star excursion balance test score: Modified star excursion balance test instrument was designed based on Hertel *et al.*[13] recommendations by placing 3 tapes in anterior, posteromedial and posterolateral directions on a nonslip surface. Angle between anterior and posteromedial/posterolateral lines was 135^0, and angle between posteromedial and posterolateral line was 90^o (360^0 full circle).Length of tape in each direction was kept 120 cm which can measure up to least millimeters. The subjects viewed an instructional video which demonstrated the test and testing procedure as explained by Plisky *et al.* which likely to increase efficiency of testing protocol and standardizes instruction.[14] Hertel *et al* found a significant learning effect with the SEBT where the longest reach distances occurred after six trials followed by a plateau.[15] Therefore, the subjects practiced six trials on each leg in each of the three reach directions followed by 5 minutes of rest prior to formal testing. The subjects were tested within 20 minutes of practicing. All the subjects were off shoes during the performance of the test as individuals attend testing in a variety of footwear so it is difficult to standardize. The subject stood on one leg on the center grid with the most distal aspect of the toe at the starting line. The trial was discarded and repeated if the participant lifted the heel of the stance leg off the ground, lost balance, came to rest at maximal reach distance, or could not return to the beginning position, reached the maximum balance time of 30 seconds. Distances were marked with chalk on the floor immediately next to the athletic tape that

Table 3: Correlation between latency period (LP) of transverse abdominis and vastus lateralis with normalized posteromedial reach distance (NRPM) of modified SEBT

		NRPM	LP (ms)
NRPM	Pearson Correlation Coefficient	1	-.718**
	r value		.000
	N	30	30
LP (ms)	Pearson Correlation Coefficient	-.718**	1
	r value	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 7: Plot chart between latency period (LP) of transverse abdominis and vastus lateralis with normalized posteromedial reach distance (NRPM) of modified SEBT



corresponds to the site of touchdown.

The distance from center of grid to the point of touchdown was measured with a measuring tape and recorded to the nearest millimeter and chalk mark was removed after each reach to reduce visual cues. In order to improve the reproducibility of the test and establish a consistent testing protocol, a standard testing order was utilized. The testing order were three trials standing on the right foot reaching in the anterior direction. This procedure was repeated for the posteromedial and the posterolateral reach directions. The specific testing order was right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral, and left posterolateral.

Lower Limb Length - To measure leg length, participant lied on the plinth; a mark was placed with a fine tipped marker on the participant s most inferior aspect of each anterior superior iliac spine and on the most distal portion of medial malleolus. The subject lift hips off the plinth and returned them to starting position. The examiner passively straightened the legs to equalize the pelvis. The subject's limb length was measured in centimeters from the anterior superior iliac spine to the most distal portion of the medial malleolus with a cloth tape measure.

The greatest successful reach for each direction was normalized by dividing reach distance with limb length multiplied by 100 and was used for comparison of latencies between direction specific muscle of SEBT and transverse abdominis of ipsilateral side.

Data analysis

All data were entered into SPSS 19.0 for statistical analysis. Descriptive statistics, including age, height (m.), weight (kg.), BMI were calculated.

A two tailed correlation tests was used in order to determine whether relationships exist between core stability (latency period) of transverse and direction specific muscles of modified SEBT test and reach score in that direction. Mean normalized anterior, posteromedial and posterolateral reach distance of modified SEBT was used for correlation analysis. The level of significance for the statistical tests was set at $p=0.05$.

Discussion

The participating collegiate recreational athlete (n=30) in this study had means height (168 cm ± 7 cm), mean weight (59.41±7.01 kg), mean age (21.46 ± 2.219) and mean BMI (21.16 ± 2.29). Statistically significant, strong negative correlation between measure of core stability (latency period) and components of modified SEBT was found ($p<0.001$). Muscles of core are the structure that provide strong base of support for extremity function and force transfer. Sports are dynamic event which requires optimal dynamic balance and early recruitment of core muscles especially transverse abdominis, as this muscle is mainly linked with core stability. Hence an objective assessment of core stability along with various destabilizing situations is very important. Balance exercises can be considered a type of core stability training in that these exercises activate the core musculature.[16] Sudden perturbations applied to the body during competition can potentially move the center of gravity outside the base of support. To avoid losing balance and falling, postural adjustments are made to move the center of gravity back inside the base of support. These postural adjustments require activation of the core musculature to stabilize the lumbar spine. Because sports skills are oftentimes performed off balance, greater core stability provides a foundation for greater force production in the upper and lower extremities. Furthermore, the sensitivity of afferent feedback pathways can be improved with balance and motorskill training[17] resulting in quicker onset times of stabilizing muscles.[18]

Core stabilization relies on instantaneous integration among passive, active, and neural control subsystems Neuromuscular control is critical in coordinating this complex system for dynamic stabilization.

Dynamic balance is a key component of injury prevention and rehabilitation in sports. Training the core muscles has been hypothesized as an intervention for improving balance. However, there is a lack of current scientific evidence to support this claim. Effects of core stability programme on dynamic balance as measured by star excursion balance test were compared. Maximum excursion distances improved for the exercise group, compared with the control group. This result justifies the hypothesis that core strengthening can improve dynamic postural control.[19] There are studies reporting improvement in dynamic balance through neuromuscular training.[20,21] Hodges and Richardson examined the sequence of muscle activation during whole body movements and found that some of the core stabilizers (i.e., transverses abdominis, multifidus, rectus abdominis, and oblique abdominals) were consistently activated before any limb movements.[4] As stated by Kibler *et al* the larger muscles of the core create a rigid cylinder and a greater moment of inertia against body perturbation while allowing a stable base for mobility.[22] When the transverse abdominus contracts, the intra-abdominal pressure increases and tenses the thoracolumbar fascia. These contractions occur before initiation of limb movement allowing the limbs to have a stable base for motion and muscle activation.

Literature in recent year has consistently linked the changes of activity onset of TrA as a marker of motor dysfunction (a component of core stability).It signifies that early the firing of TrA , better the core stability.[23] Core stability comprised of components such as core strength, endurance, power, balance, as well as the coordination of the spine, abdominal, and hip musculatures.[24] Therefore, it is necessary to describe the multifaceted components of core stability.

Researchers suggest that strong and endurable core muscles stabilize the spine favorably by providing greater passive support with effective mechanical integrity and enhanced neurological recruitment patterns; including timely activation of these muscles when exposed to forces and loads.[25] Above mentioned research studies strongly support our finding because core stability is directly linked with early recruitment of core musculature especially transverse abdominis before any limb movement as well as stronger the core stability better the dynamic balance, so it signifies that latency of transverse abdominis with direction specific prime mover of modified SEBT will be correlated.

Conclusion

In our study we found that latencies between transverse abdominis and direction specific muscle of SEBT to be highly correlated with each other, so it can be used as an objective assessment tool of core stability along with the modified SEBT score analysis. Present study has added a new dimension to core motor control and its relation to balancing abilities so; it can be used as a screening tool of various performance components in different variety of sports on the basis of EMG.

It could be inferred through this study that a component of balance is involved while training core muscles through neuromuscular training

Limitations of study

A larger sample size would have been better as it would help in generalizing the results. Our study focused only on transverse abdominis muscle of core stabilizing system, but this muscle does not alone represent the whole core stability .

Future perspectives

Future researchers should attempt to include larger samples, a greater variety of sports (as there may be other activities that require greater core control), elite athletes, and a more demographically diverse sample.

The significance of this research could be enhanced by including low back pain population.

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