Original Article

Indian Journal of Forensic Medicine and Pathology
Volume 12 Number 2, April - June 2019
DOI: http://dx.doi.org/10.21088/ijfmp.0974.3383.12219.8

Core Muscles Electromyographic Analysis in Collegiate Athlete on Performing Deadlift on Different Unstable Surfaces

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Abstract

Aim: Muscle activity analysis during deadlift is an important tool for assessing the effectivity of the exercise. Some studies indicate difference in muscle activities when collegiate athletes perform it on unstable surface. *Materials and Methods:* In this study, thirty collegiate male athletes were recruited. MVIC was recorded for each deadlift exercise. *Results:* Isometric deadlift executed on BOSU ball resulted in greater % MVIC change in core muscles ($p<0.05$), i.e., transversus abdominis and multifidus while no statistical difference was found when dynamic deadlift was executed on both surfaces ($p>0.05$). *Conclusion:* Isometric deadlift exercise result in significant change in muscle activity as compared to dynamic deadlift.

Keyword: EMG; BOSU; TrA; Multifidus; Athletes.

How to cite this article:

Fozia, Saurabh Sharma, Shalini Sharma et al. Core Muscles Electromyographic Analysis in Collegiate Athlete on Performing Deadlift on Different Unstable Surfaces. Indian J Forensic Med Pathol. 2019;12(2):95-105.

Introduction

Owing to the increasing usage by athletes and recreational trainers, the concept of core training has gained popularity in the recent years [1,2]. The athletes aimed at improving performance or those using therapeutic training have core exercises as the most essential component of their exercise regimen [3]. The axial skeleton along with the soft tissues originating from it constitute the core [4]. There is sequential carryover of force generated in the upper extremity through the core to the lower extremity [5,6]. Various researchers advocate the interlinkage in performance of sports specific tasks and muscles of core and limb with a decrease in performance and increased risk of injury attributed to a weak core that is inefficient in transferring the forces [7-13]. There is reported incidence of injury because of alteration of the lower extremity kinematics during maximal cycling exercises when the core was fatigued beforehand [7]. It has been proposed that a weak core is predictive of injury in the Anterior cruciate ligament and iliotibial band along with patellofemoral pain, improper landing kinematics and low back pain and an emphasis has been placed on optimising core stability for injury prevention [14-19]. There is contraction of the multifidus and transversus abdominis, 110 ms and 30 ms prior to movement of leg and shoulder respectively in healthy individuals in order to stabilise the lumbar spine [20,21]. Multifidus and transversus abdominis contract in a delayed manner before limb movement in patients with low back pain [20], with an atrophy of multifidus

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Received on 28.02.2019, **Accepted on** 26.03.2019

in chronic low back pain patients [22]. Training core muscle can be accomplished through any of these approaches with close chain exercises on surface with stability, surface without stability and open kinetic chain exercise on both surfaces with support [4]. Quite recently, the concept of using balls, platforms and other devices with resistance training in order to faster varying degrees of instability [23]. One such apparatus (Both Sides Up balance trainer) for balance training comprises of an inflatable rubber bladder mounted on a solid plastic base that resembles a halved Swiss ball (BOSU; Fitness Quest, Canton, OH). In contrast to traditional resistance training that makes use of floor and stable benches, larger stresses are placed on the neuromuscular structures when making use of instability resistance training owing to greater instability of the unstable platform as compared to the traditional resistance training carried out using floor and stable benches [23]. Improvements in muscle cross sectional area and neuromuscular coordination leads to strength gains [24]. Administration of instability training has been postulated to be improving the core stability nevertheless, there are mixed evidences of enhanced trunk and abdominal musculature following use of unstable surface [23]. A study comparing effects of traditional floor exercises to Physio ball training found out improvement of torso balance and trunk electromyographic activity by the latter one within five weeks [25]. In other studies by Stanforth et al. [26] , resistance balltraining was found to be more effective for back and abdominal muscle as compared to traditional floor work. There is an increase in muscle activation, with use of an unstable surface required for completion of exercises in a controlled manner [27]. There was a reported 37-54% Increase in trunk stabiliser activity during unstable base chest press in comparison to chest press using a stable base [5]. Trunk stabiliser activity was found to be increased when curl ups were performed on an unstable surface and labile surfaces led to an elevated activity of abdominals [27,28]. Contrary to above mentioned findings some of the studies demonstrated EMG findings of core and lower limb muscle to be inefficient while using an unstable surface [29,30,31].

Most of the studies mentioned above took into consideration the differences in exercises done on stable versus unstable surfaces with only a few evidences comparing the two unstable surfaces with respect to Instability Resistance Training (IRT). As per the recent updates, no study has been performed with two unstable surfaces (Rocker board and BOSU ball) in regard to Instability Resistance Training and simultaneously comparing electromyographic profile of the core muscles (transversus abdominis and multifidus). This study aims at analyzing and comparing the electromyographic activity of the core muscles during deadlift done on rocker board and BOSU ball and to find out which of the two is best suited for maximal core muscle activation.

Methodology

Subject

Recruitment of 30 collegiate male athletes was done for the study from Jamia Millia Islamia. (Height 1.69m ± 0.05m, Weight 74.7 ± 6.5 kg, Mean ± SD age 22.1 ± 1.18 years, and BMI 26 ± 1.5) (Table 1). Having completed the physical activity fitness questionnaire, all subjects were found to be healthy and identified as having a good balance by completing star excursion balance test. Healthy male subjects between the age group of 21 to 24 years with absence of any adjoining musculoskeletal disorder were included in the study. All the selected athletes were already involved in a sport- specific training atleast twice weekly and competitive play once weekly. The exclusion criteria included any musculoskeletal pain history (knee or ankle injuries and acute or chronic low back pain), pulmonary problem, neurological disorder and cardiovascular dysfunction and smokers.

Procedure

The ethical clearance for the research study was obtained from ethical committee of the university. Study was conducted in the Physiotherapy

Table 1: Descriptive statistics of Demographic Data

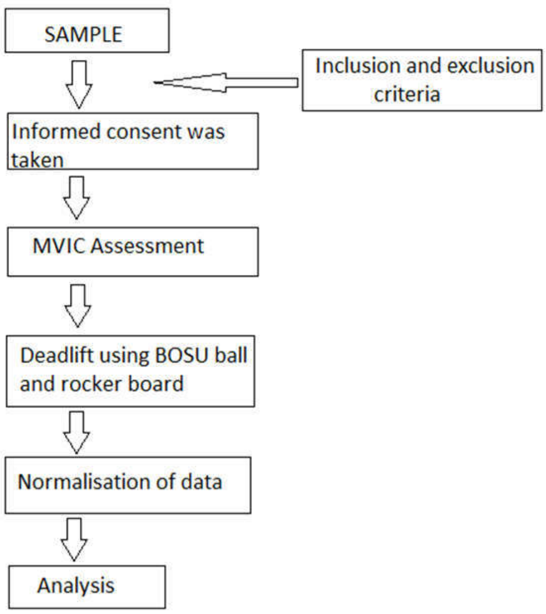
Variables	Mean (n=30)	Standard deviation (SD)
Age (yrs)	22.10	1.18
Height (m)	1.69	0.057
Weight (kg)	74.7	6.49
BMI (wt/Ht2)	26.07	1.50
60%1 RM(Kg)	66.63	14.86

SD: Standard deviation; BMI: Body Mass Index; RM: Resistance maximum; wt: weight in kg, Ht^2: height in metre square

Centre of the university. Selection of the subjects was done on the basis of inclusion and exclusion criteria. An informed consent was obtained from participants and a number was assigned for record keeping. Procedural aspects and nature of the study along with any doubts the subjects were having were cleared prior to initiation of the protocol. Stadiometer and digital weighing machine were used for measuring the height and weight of the athletes respectively.

Study design

Table 2: Study design



Familiarization

Two familiarization sessions were given to all the participants prior to the study. Sufficient time was given to the subjects to practice on rocker board and BOSU ball. A knee flexion angle of 100 degrees was emphasized at the time of deadlifts. After administering the specifically designed familiarization session, the subjects were instructed neither to perform any exhaustive exercise before 48 hours of testing nor to consume any energy or caffeine drink 2 hours preceding testing procedure.

Testing procedures

National Strength and Conditioning Association tables were used for calculation of 1 RM for the subjects before testing procedures [32]. All the subjects underwent warm-up sessions 72 hrs prior to collection of data. Warm up exercises included submaximal aerobic activity, shorts bouts of dynamic muscle stretching followed by 3 Maximal Volumetric Isometric Contraction of transversus abdominis and multifidus for a duration of 3 seconds. Subjects performed both deadlift variants (isometric and dynamic) on rocker board and BOSU ball, three days following MVIC measurement Same evaluators were strictly controlling the measurement procedure during the data collection process.

Surface EMG preparation

Before beginning the experimental phase all subjects were prepared for EMG recording. Excess hair was shaved off the skin followed by use of alcohol swab and abrasive to reduce skin resistance (≤ 10 kOhm). The SEMG was recorded with the help of AD Instruments Bioamplifier (Aust) (Fig. 1). Bipolar disposable surface electrodes (Ag/AgCl) with 1 cm diameter were attached on the right side (unilaterally) over the local trunk muscles, parallel to the muscle fibre orientation.

Fig. 1: AD instrument Power Lab

Local muscle activity was represented by inferior fibre of the internal oblique [33,34] because fibres of internal oblique and Transversus abdominis are blended at a site medial and inferior to ASIS [35]. Transversus Abdominis/Internal Oblique muscles lie 2 cm anteromedial to the ASIS [35]. Activity of the multifidus can be recorded, rostrally and caudally to a line passing through both PSIS, lateral to midline of body [37,38]. Recommendations suggest a maximum spacing of 2.5 cm between recording electrodes [39]. Ground electrode mounting of was done on bony prominence of left iliac crest over the superior aspect [40]. (Figs. 2,3).

Fig. 2: Placement of surface electrode for Transverse abdominis muscle

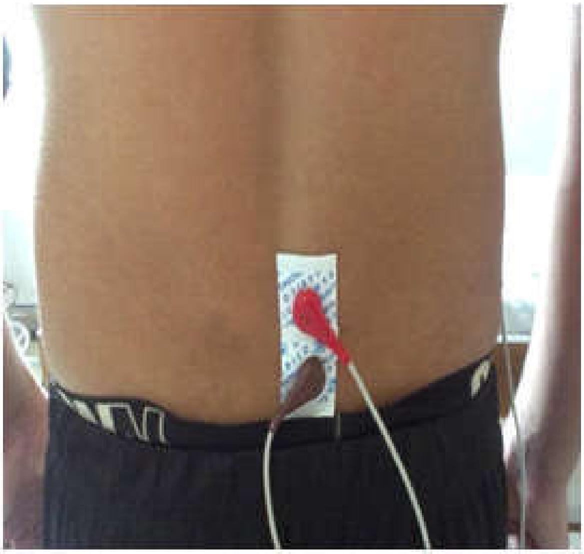


Fig. 3: Placement of surface electrode for multifidus muscle

Maximal voluntary isometric contractions (MVIC) assessment

Three experimental trials were done to provide normalisation of the muscle's MVIC [41-47]. EMG normalisation is done corresponding to the maximal EMG amplitude in order to allow comparisons of inter individual scores to maximum for each individual [48]. Compounding variables like skin impedance, electrode orientation, amount of subcutaneous fat or introduced if normalisation of EMG is not done prior to quantitative analysis [48]. Exercises were performed in two different ways that included providing verbal cues and manual resistance to elicit maximal effort. Using abdominal hollowing when performing a maximum expiratory maneuver in a sitting position recorded the maximum activation of Transversus Abdominis (Fig. 4). Performing trunk extension with the subject in prone lying position, legs strapped to table and applying maximal resistance on the dorsal aspect of scapula recorded the maximum multifidus activation [27,50,42,51,43] (Fig. 5).

Fig. 4: MVIC procedure for Transverse abdominis muscle

Fig. 5: MVIC procedure for multifidus muscle

Subjects will have a MVIC trial that needs them to sustain maximal effort for a duration of 3 seconds. A one minute rest period was used between each trial. Isometric phase of three seconds was used to collect the EMG data. The highest signal intensity in 1 sec period constituted the MVIC recording [49].

Exercise Procedures

A load of 60% of 1 RM was used to perform deadlift on two different surfaces. The choice of 60% relative load reflects the lowest load recommended to be used in strength training [50]. Furthermore, the maximum permissible load limit on unstable surface is 70% of 1 RM [4]. The sequence of exercises was isometric followed by dynamic deadlifts. In order to avoid fatigue, the order of activities in the two conditions (rocker board and BOSU ball) was counterbalanced.

Isometric Deadlift

The subjects stands with feet kept flat below the bar, performs a squat, grasping the bar with hands kept shoulder width apart with a mixed or overhead grip. A knee flexion angle of 100 degrees was used along with slight hip flexion [51]. Above mentioned exercise was performed by all subjects for a trial duration of 5 seconds under both the protocol conditions (rocker board and BOSU ball). To ensure complete recovery the subject is provided with resting time of 5 minutes between conditions [30]. (Figs. 6a, 6b).

Fig. 6a: Isometric deadlift on BOSU ball

Fig. 6b: Isometric deadlift on rocker board

Dynamic Deadlift

Maximum permitted range for knee flexion was restricted to 100 degrees [52]. The bar was kept as close to body as possible and lifted using legs and hips keeping arms and back erect. Metronome was used to control the execution speed so that each phase lasted for a duration of 2 seconds. (Fig. 7a, 7b).

Fig. 7a: Dynamic deadlift on BOSU ball

Fig. 7b: Dynamic deadlift on rocker board

A load of 60% of 1 RM was used and a set including six repetitions was performed by the subjects for both the conditions under consideration. In order for the athlete to completely recover, a rest time of five minutes was used following each condition [30].

Normalization of data

Surface EMG data collection was performed both during the dynamic and isometric deadlift exercise phases. Middle two second period of surface EMG signals of the isometric exercise were analyzed. Analysis for the dynamic exercise used surface EMG signals for the complete phase. Three successive readings were recorded for each muscle and their average taken as a whole was used for providing a basis for normalization of surface EMG amplitudes fetched in experimental exercises.

Statistical analysis

Data were analysed using SPSS version 21.0. Shapiro-wilk was used to verify the normality of variables distribution. Paired t test was used to check the difference between muscles concerning both MVIC and experimental exercises. The confidence interval used was 95% with level of significance was set at $p<0.05$.

Results

Transverse abdominis

Results showed a significant difference in activity of transverse abdominis when isometric deadlift performed on BOSU ball (mean 23.35, SD 9.42) and rocker board conditions (mean 20.84, SD 9.24) at t (29)=2.6, p= 0.014 [Tables 3,4] [Fig. 8a]. The MVIC of TrA was found to be 0.522 ± 0.227.

Results showed no significant difference in dynamic activity of transverse abdominis when dynamic deadlift performed on BOSU ball (mean 21.65 SD 8.9) and rocker board conditions (mean 22.56 SD, 9.29) at t(29)= -1.08, p=2.87 [Table 3,4] [Fig. 8b].

Table 3: Mean and standard deviation of maximal voluntary isometric contractions (MVIC) of transverse abdominis and multifidus.

	Mean	SD
Transverse Abdominis (TA)	0.522	0.227
Multifidus (MF)	0.922	0.168

SD: standard deviation; TA: transverse abdominis; MF: multifidus

Table 4: Paired t-test analysis of surface electromyography of each tested muscle between both the unstable conditions.

Variables	BOSU mean SE	Rocker mean SE	t value	P value	CI
TAIDL	23.35 1.72	20.84 1.68	2.6	0.014*	4.47 - 0.543
MFIDL	116.89 3.89	100.86 4.34	3.607	0.001*	25.12 - 6.94
TADDL	21.65 1.64	22.56 1.69	-1.08	2.87	0.803 - (- 2.62)
MFDDL	101.18 4.25	109.44 4.13	-1.89	0.068	0.645 - (- 17.16)

TAIDL: Transverse Abdominis Activity During Isometric Deadlift; MFIDL: Multifidus Activity During Isometric Deadlift; TADDL: Transverse Abdominis Activity During Dynamic Deadlift; MFDDL: Multifidus Activity During Dynamic Deadlift Activity; data are presented as Mean, SE = Standard Error; CI = Confidence Interval; * Significant difference

Multifidus

Results showed a significant difference in activity of multifidus when isometric deadlift performed on BOSU ball (mean 116.89, SD 21.32) and rocker board conditions (mean 100.86, SD 23.78) with t(29)=3.604, p=0.001 [Tables 3,4] [Fig. 8a]. The MVIC of multifidus was found to be 0.922 ± 0.168.

Result showed no significant difference in activity of multifidus when dynamic deadlift performed on BOSU ball (101.18 and SD 23.26) and rocker board conditions (mean value 109.44 SD 22.64) with t (29)=1.89, p=0.068 [Tables 3,4] [Fig. 8b].

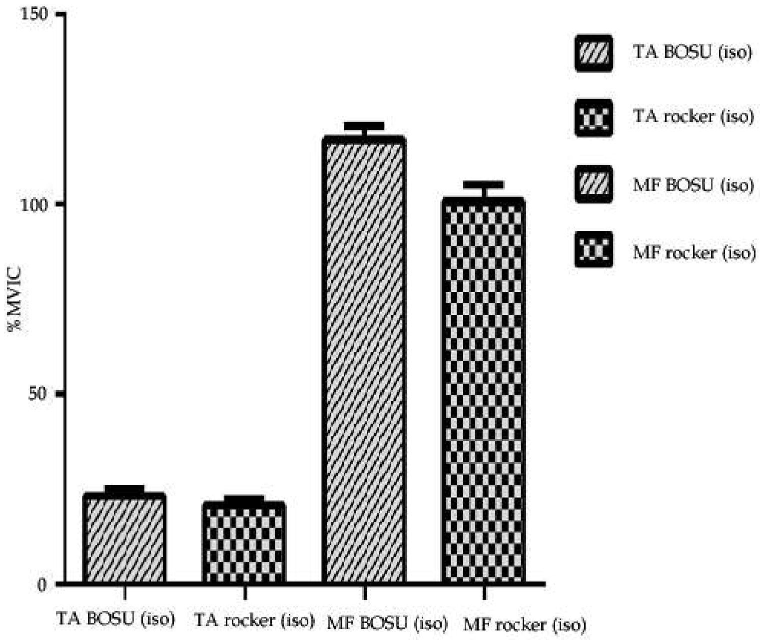


Fig. 8a: Comparisons between conditions related to the surface electromyography of each of the tested muscle. % MVIC: percentage maximum voluntary isometric contraction; iso: isometric deadlift; TA: Transverse Abdominis; MF: Multifidus. Each bar represents mean and standard error (SE). Significant difference ($p< 0.05$) between the conditions.

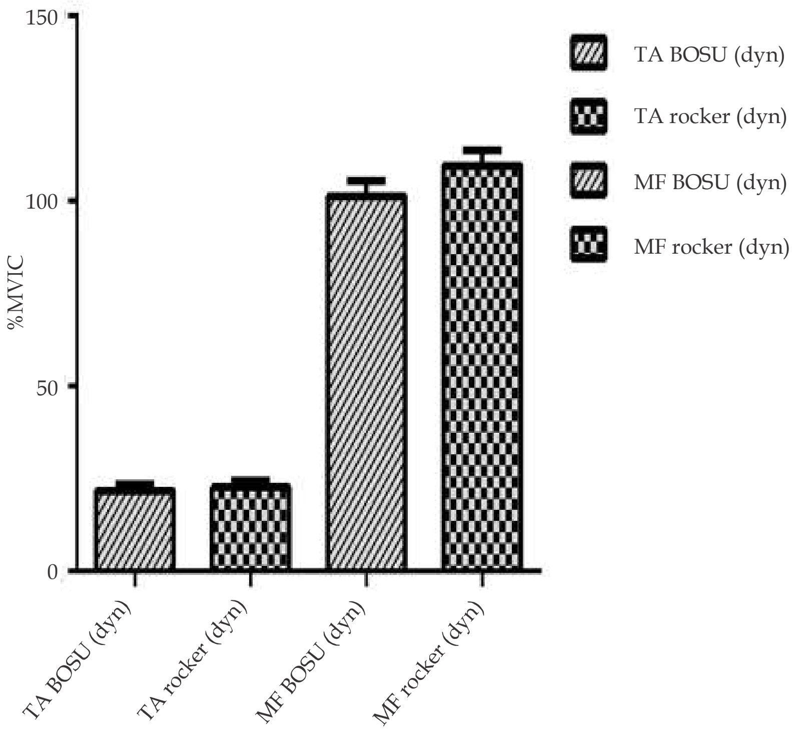


Fig. 8b: Comparisons between conditions related to the surface electromyography of each of the tested muscles. % MVIC: Percentage Maximum Voluntary Isometric Contraction; dyn: Dynamic Deadlift; TA: Transverse Abdominis; MF: Multifidus. Each bar represents mean and standard error (SE). Significant difference ($p>0.05$) between the conditions.

Discussion

Core muscle's motor control and coordination is much necessary as compared to strength training or trunk muscle activation in low back pain patients. A number of studies report core muscle motor control deficits in low back pain patients [53]. Increased contribution of IRT is attributed to increase in stability, proprioception and balance rather than gain in strength [23]. Well designed strength training program includes deadlift as their key component [54,55,56]. This investigation suggests these exercises to be effective in promotion and maintenance of stability of the core. Earlier researches involved comparison of calisthenic exercises performed on stable and unstable surfaces or the performance of lifts on a stable surface compared to the use of unstable surface for calisthenic exercises. This is one of the few studies that compared deadlift exercise on two different types of unstable surfaces BOSU ball and rocker board.

These results are in compliance with the study by Saeterbakken et al. (2013) [57] who found that on increasing the instability condition there is an increase in EMG activity of the rectus femoris. Morinkovic et al. (2011) [58] concluded that gains in muscular outputs of 1 RM, power velocity and force were sufficient when BOSU ball was used for unstable squat training at 50% of 1 RM for 8 weeks. Another study found two unstable surfaces to be less efficient than a stable surface in generating force and EMG in core muscles, but between the two unstable surfaces BOSU ball showed greater percentage mean MVIC of paraspinal muscles on performing deadlift as compared to T – bow [30]. In one of the studies by Joshi et al., vertical jump performance and dynamic balance were improved in football players following 5 weeks of balance training on BOSU ball [59]. In accordance to the results of our study, Paterno et al. (2004) [60], showed significantly improved single limb stability following 6 weeks of balance training on BOSU ball in young female athletes.

A number of authors had demonstrated that instead of performing an exercise on stable surface, exercising on unstable surface provides a better means of increasing the activity of the core muscles [61,62,63]. Chest press while performing pushups and squat on a Physio ball increased abdominal muscle activity and perceived exertion were reported [64,65]. Another study concluded that higher degree of instability while doing squat (smith machine v/s Olympic squat v/s inflatable disc) resulted in a 20-30% greater activation of stabiliser muscles of the spine [66].

Past researches on unstable surfaces have pointed to increased importance of the inflation of BOSU ball and curvature of rocker board. The angle of deflection of the rocker board can be in the range of 20° to 90° [67].

Earlier evidences advocate that activity of core muscles increase following increased instability and hence redirects to the inference that BOSU ball creates more instability than a rocker board. One of the reasons for this may be multiplanar instability provided by BOSU ball as compared to unidirectional instability of rocker board. Instability increases in direct proportion to increase in inflation of the BOSU ball. These reasons provide justification for more effectiveness of BOSU ball in comparison to rocker board for activation of core muscles.

Clinical implication of the study

- Stability exercise for core muscles can include isometric deadlift using BOSU ball as a preventive and rehabilitative exercise in patients with low back pain and furthermore helps in reduction of injury owing to enhancement of motor control.

Limitations

- During the course of testing the degree of inflation would have been more than ten inches or knee angle be more than 100 degrees can lead to lesser activation of core muculature.

Perspective for future study

- Analysis of compressive and shear loading on the spine during isometric and dynamic deadlift activities using biomechanical model including kinematic and kinetic data.
- Load sensors should be used for actual monitoring the angles at knee and hip.

Conclusion

In conclusion, the available evidence suggests that dynamic deadlift on rocker board and BOSU ball does not have a marked effect on the activity of multifidus and transversus abdominis activity in athletic population. However isometric deadlift on BOSU ball lead to significant gain in the activity of core stabiliser muscles Therefore, to increase the activity of local trunk stabiliser muscles, BOSU ball is more advantageous to use for execution of deadlift.

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