Deadlift Muscle Force and Activation Under Stable and Unstable Conditions

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Abstract

Chulvi-Medrano, I, García-Massó, X, Colado, JC, Pablos, C, Alves de Moraes, J, and Fuster, MA. Deadlift muscle force and activation under stable and unstable conditions. *J Strength Cond Res* 24(10): 2723–2730, 2010—The objective of this study was to compare the production of force and paraspinal muscle activity between deadlifts carried out in a standard way and with different instability devices (Bosu and T-Bow). Deadlifts involve the performance of muscle activities with dynamic and isometric characteristics. Thirty-one subjects participated voluntarily in the study. Initially, they performed an isometric test for 5 seconds in each condition. After that, they performed a set of 5 repetitions with 70% of the maximum isometric force obtained in each one of the previously evaluated conditions. During the isometric tests, records of electromyographic activity and force production were obtained, whereas during the dynamic tests, only the electromyographic activity was registered. The subjects produced more force and muscle activity on the stable surface than under the other conditions during the isometric test ($p < 0.05$), and the same differences in muscle activity were observed during the dynamic test ($p < 0.05$). These data show that the performance of deadlifts under stable conditions favors a higher production of maximum strength and muscle activity. Therefore, we conclude that the use of instability devices in deadlift training does not increase performance, nor does it provide greater activation of the paraspinal muscles, leading us to question their value in the performance of other types of exercises.

Key Words instability, core, Bosu, electromyography

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Introduction

Core training has proved its effectiveness in improving back health both in the general population (23) and among athletes (12,16). In addition, previous studies have demonstrated the negative effect of weak core musculature on distal limbs (37).

Traditionally, the strengthening of this region has emphasized "isolation" training, which places an emphasis on mobilizing muscles (27). However, because stability is important for lumbar health (27,29,30), the specificity of core training has been geared to generate stimuli that trigger the stabilization role of the core muscles (15,24).

One result of this modification in core training has been the appearance of specific devices to create unstable environments, such as the fitball (14) and the Bosu (31). The use of these devices seems to increase the levels activation of stabilizing muscles because, as expressed by McIlroy and Makin (25), instability and disturbance generate muscular reactive postural responses, which in the case of the lumbar spine area ensures a neutral zone (15,19,24,30). It was also recently shown that ground-based free weightlifting exercises, such as deadlifting and squats, cause moderate lumbar instability when carried out with a load $\geq$ 70% 1 repetition maximum (1RM) (2,3). Several authors have shown that this kind of exercise produces a more efficient stimulus for stabilizing core strength than can be achieved by specific callisthenic exercises (11) or by doing the same exercise with a lesser load on unstable surfaces (36).

Despite the fact that, initially, unstable surface training was reserved for rehabilitation programs, today this type of training is included in strength and conditioning programs. At first, unstable surface training was used for specific exercises for the core, such as curl-ups. There are studies with opposite results regarding the efficiency of these exercises in achieving higher electromyogram (EMG) amplitude (13,32). Currently, the use of these devices has been incorporated into traditional exercises to promote neuromuscular coordination and patterns of neuromuscular recruitment and reduce the rate of injury, but there is much disagreement on the effects of this combination for sport performance and for core stability activation (1,35).

Behm and Anderson (1) suggest that the inclusion of instability devices in resistance training can be sensed mechanically because, according to trainers and coaches, instability resistance training may increase muscle activation to a greater extent than traditional resistance training methods that use more stable benches and floors because the former improves afferent nervous efficiency, which reduces injury and improves performance. For instance, Marshall and Murphy (21) compared muscle activity in the rectus abdominis, transversus and internal oblique abdominis, external oblique abdominis, and erector spinae when push-ups were performed on a fitball vs. a stable floor. The results demonstrated that at the top portion of the unstable push-up (using the fitball), there was significantly greater activity in the rectus abdominis (35 vs. 9% of maximal activity) and the transversus and internal oblique abdominis (33 vs. 13% of maximal activity).

Recent reports have revealed that training on an unstable surface offers no increase in the EMG for core training and no increased performance in athletes (8,11,18,28). Cressey et al. (8) compared unstable training using inflatable rubber discs with stable conditions in 19 elite soccer players. The group that trained under unstable conditions exhibited lesser performance improvement than the group that trained under stable conditions.

The diversity of data has invited the suggestion that the proper postural alignment–maintaining a stable neutral zone–during postural exercises that stress the lower back could stimulate activation of the core as much as or more than with the variants involving instability (1,38,34).

The purpose of this research was to compare the muscular performance attained and the activation of paraspinal trunk muscles during an Olympic bar deadlift exercise under stable and various unstable conditions. The hypotheses of this study were the following: (a) maximum isometric strength would be lower under unstable conditions and (b) the muscular activity of certain paraspinal muscles would be the same or less for unstable exercises compared with the stable exercise.

Methods

Experimental Approach to the Problem

To examine differences in muscle strength and activation between a stable and unstable surface, a within-subject counterbalanced design was used. The maximal isometric effort (maximum isometric voluntary contraction [MIVC]) and dynamic effort (70% MIVC) when performing deadlifts with an Olympic bar were evaluated under both the stable and unstable conditions using Bosu and T-Bow devices. Deadlifting was chosen as the polyarticular free weightlifting exercise, because it requires considerable inter and intramuscular co-ordination and can trigger moderate instability in the lumbar region when carried out with loads ≥ 70% 1RM (2,3), which means that trunk stabilizer muscles are needed for a correct load transfer and for the movement to be possible. Surface electromyography (SEMG) activity of the lumbar multifidus spinae (LM) and thoracic multifidus spinae (TM) and the lumbar erector spinae (LE) and thoracic erector spinae (TE) was recorded under isometric and dynamic test conditions in addition to force signals during the isometric condition test. Surface electromyography signals were normalized by the maximum voluntary activity achieved during the back extension exercise that was recorded before data collection. Therefore, the dependent variables of this study related to the SEMG were the maximum and average root mean square (RMS) in dynamic and isometric contractions. The dependent variable related to force signals was the maximum isometric force. The intra-class correlation coefficient showed good test–retest reliability (0.75–0.82).

Subjects

Thirty-one subjects (24.29 ± 0.48 years; 167.98 ± 8.11 cm; 79.08 ± 2.37 kg), all students from the School of Sciences of Physical Activity and Sports at the University of Valencia (Spain) with 1 year of minimum experience in strength training, participated voluntarily in this study. The subjects included in the research had a minimum of a year's experience in recreational resistance training and were familiar with instability training because they reported having trained regularly on unstable surfaces, such as the Bosu, the FitBall, inflatable discs, and the T-Bow. No subjects included in this study had any musculoskeletal pain, none suffered from any neuromuscular disorders, and none had any form of joint or bone disease. No subject was taking any form of performance-enhancing medication.

All subjects signed an informed consent form before starting the protocol, and the study was approved by the institutions' review board.

Procedures

All procedures were performed in the spring. Seventy-two hours before data collection, after performing a warm-up protocol, each subject performed a back extension at maximum isometric effort in the prone position for 5 seconds to obtain the MIVC of the paraspinal muscles.

Subjects had performed no strength training for 48 hours before data collection and were advised to maintain their nutritional habits and to avoid stimulatory substances (e.g., caffeine). The measurement protocols were always strictly controlled by the same evaluators. All subjects were familiar with the tests and the exercise, so no familiarization session was necessary. Before starting the evaluation, height and body mass were measured. The subjects then underwent a standard warm-up, directed by the main researcher.

Subjects were required to perform isolated MICV deadlifts on a stable and an unstable surface and perform stable and unstable dynamic exercises at 70% of the MICV. This load (70% of 1RM) is the limit at which using unstable surfaces during traditional strength training produces an increase in core-muscle activation (2,3). First, the participants performed the isometric exercises and, later, the dynamic ones. In addition, the order of the exercises under the 3 conditions (stable, Bosu, and T-Bow) was counterbalanced to avoid the effects of fatigue. The Bosu is an unstable device that allows for balance and strength training. The Both Sides Up balance trainer (Bosu) (55 cm) was applied with its convex side up to generate instability. The T-Bow is a Swiss multifunctional training device usually used for movement therapy, training, and education. Recently, Chulvi et al. (6) have reported that T-Bow training in elderly people leads to increased balance. All subjects were verbally encouraged throughout all physical tests. Each test was supervised by the same examiner, with 1 reference examiner who attended to monitor strict compliance with protocol.

Isometric Deadlift. The isometric deadlift technique was previously described by Earle and Beachle (9). With feet flat beneath the bar, the exercise is performed by squatting down and grasping the bar at shoulder width or slightly wider with an overhand or mixed grip. The knees are flexed at 100°, and this is combined with a slight hip flexion. The bar was connected to a hook in the floor by a chain, into which the load sensor was integrated, to ensure that there is no movement away from the given angle.

Each subject performed a 5-second trial of this exercise under each of the conditions tested (i.e., stable, Bosu, and T-Bow). The resting time between conditions was 5 minutes to ensure complete recovery.

Dynamic Deadlift. The same considerations were followed under dynamic deadlift conditions. The range of movement for the exercise was restricted to

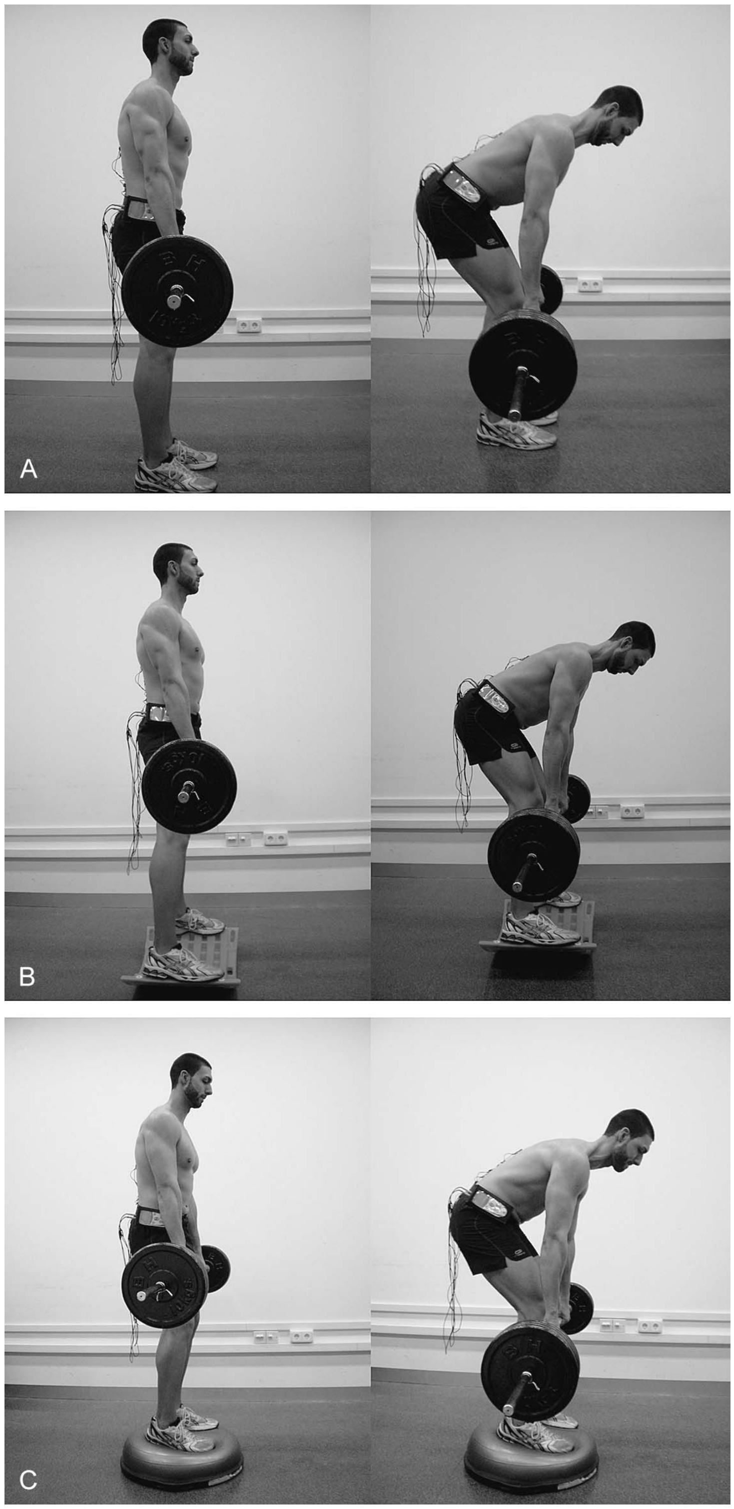

Figure 1. Dynamic exercises. From top to bottom: A) deadlift stable condition, B) deadlift T-Bow condition, and C) deadlift Bosu condition. The image on the left of each exercise shows the starting position and the image on the right shows the end position.

100° of knee flexion (7). When performing the lift, subjects kept the back rigid and arms straight and lifted the bar using the legs and hips, keeping the bar as close to the body as possible (see Figure 1). The speed of execution was controlled by a metronome to ensure that each of the movement's phases lasted 2 seconds. Each subject performed a set of 6 repetitions under each of the conditions tested, with a load of 70% of the maximum isometric force reached during the execution of that exercise when performed isometrically. The recovery time between each condition was 5 minutes, to ensure complete recovery.

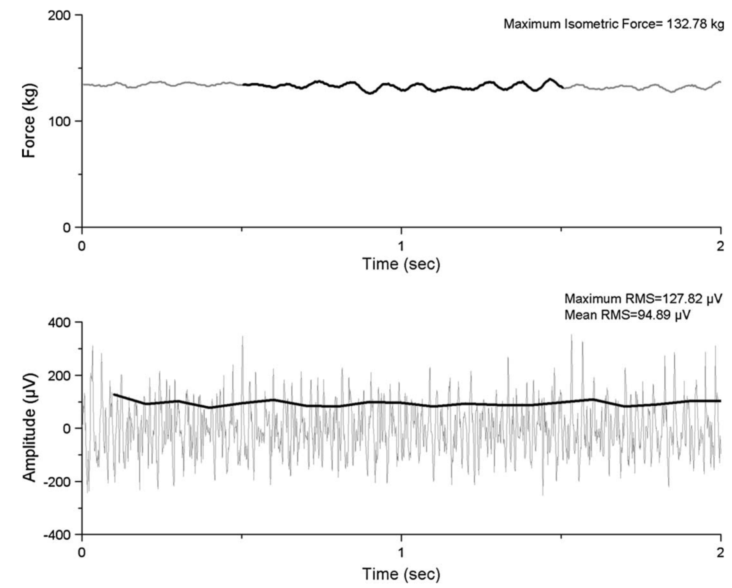

Figure 2. Example of force and surface electromyography signals. On the top layer, the gray line represents the middle 2 seconds of the signal force. The black line represents the middle second, where mean force is the maximum isometric force. On the bottom layer, the 2 analyzed seconds of raw surface electromyography signal are represented in gray, with the root mean square (RMS) in black.

Electromyography Recording. To acquire the surface electromyographic signals produced during the attempts, we used a ME6000P4 biosignal conditioner (Mega Electronics, Ltd., Kuopio, Finland). Before placing the electrodes, the skin was prepared by shaving the area and cleaning with alcohol to reduce impedance as much as possible. Pregelled bipolar Ag/AgCl surface electrodes (Blue sensor M-00-S; Medicotest, Ølstykke, Denmark) were placed with an interelectrode distance of 25 mm on the following muscle groups: (a) LM (ca. 3 cm lateral to the spinous process at L5 [28]); (b) TM (ca. 2 cm lateral to the T11–T12 spinal process [17]); (c) LE (ca. 3 cm lateral to the spinal process at L3 [5,20]); and (d) TE (ca. 5 cm lateral to the spinal process at T9 [5,20]). The reference electrode was placed between the active electrodes, approximately 10 cm away from each, as per the manufacturer's specifications (26).

All signals were acquired at a sampling frequency of 1 kHz, amplified, and converted from analog to digital. All records of myoelectrical activity (μV) were stored on a hard drive for later analysis.

Isometric Force Recording. To measure the strength created by the extensor knees and hip muscles, the bar was tied to a load cell (CTCS; Mutronic, Madrid, Spain). All signals were acquired at a sampling frequency of 200 Hz, amplified, and converted from analog to digital. All records of force (kg) were stored on a hard drive for later analysis.

Data Reduction. All SEMG and force signal analyses were carried out using Matlab 7.0 (Mathworks Inc., Natick, MA, USA). The SEMG signals related to the isometric exercises were analyzed using the middle 2-second period. On the other hand, the SEMG signals of the dynamic exercises were analyzed using the whole repetition. All signals were bandpass filtered at a 20- to 400-Hz cut-off frequency with a fourth-order Butterworth filter. Surface electromyography amplitude in the time domain was quantified using the RMS and processed every 100 milliseconds.

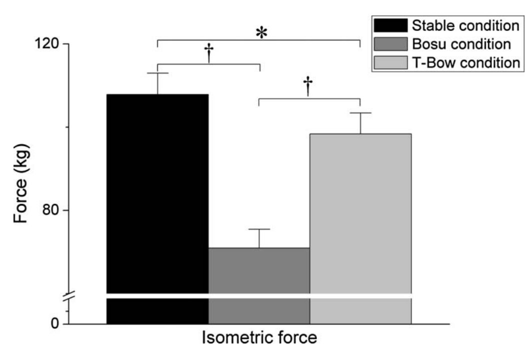

Figure 3. Deadlift force production differences between conditions. Each bar represents the mean, and the error bars the *SEM*. *Significant difference ($p < 0.05$) between groups. †Significant difference ($p < 0.005$) between groups.

TABLE 1. Surface electromyography comparisons between conditions.*

Variable	Stable condition	T-Bow condition	Bosu condition
Maximum isometric activation	107.74 (4.53)†	91.62 (4.15)	96.77 (4.23)
Mean isometric activation	102.26 (4.09)†	81.57 (3.64)	84.13 (3.38)
Maximum dynamic activation	117.38 (5.49)†	102.02 (5.77)‡	91.05 (4.41)
Mean dynamic activation	88.53 (2.97)†	72.51 (2.31)	71.78 (2.55)

*Data are expressed as mean (*SEM*) in percentage of the maximum isometric activation during back extension ($n = 31$).
†Significant differences ($p < 0.05$) related to T-Bow and Bosu conditions.
‡Significant differences ($p < 0.05$) related to the Bosu condition.

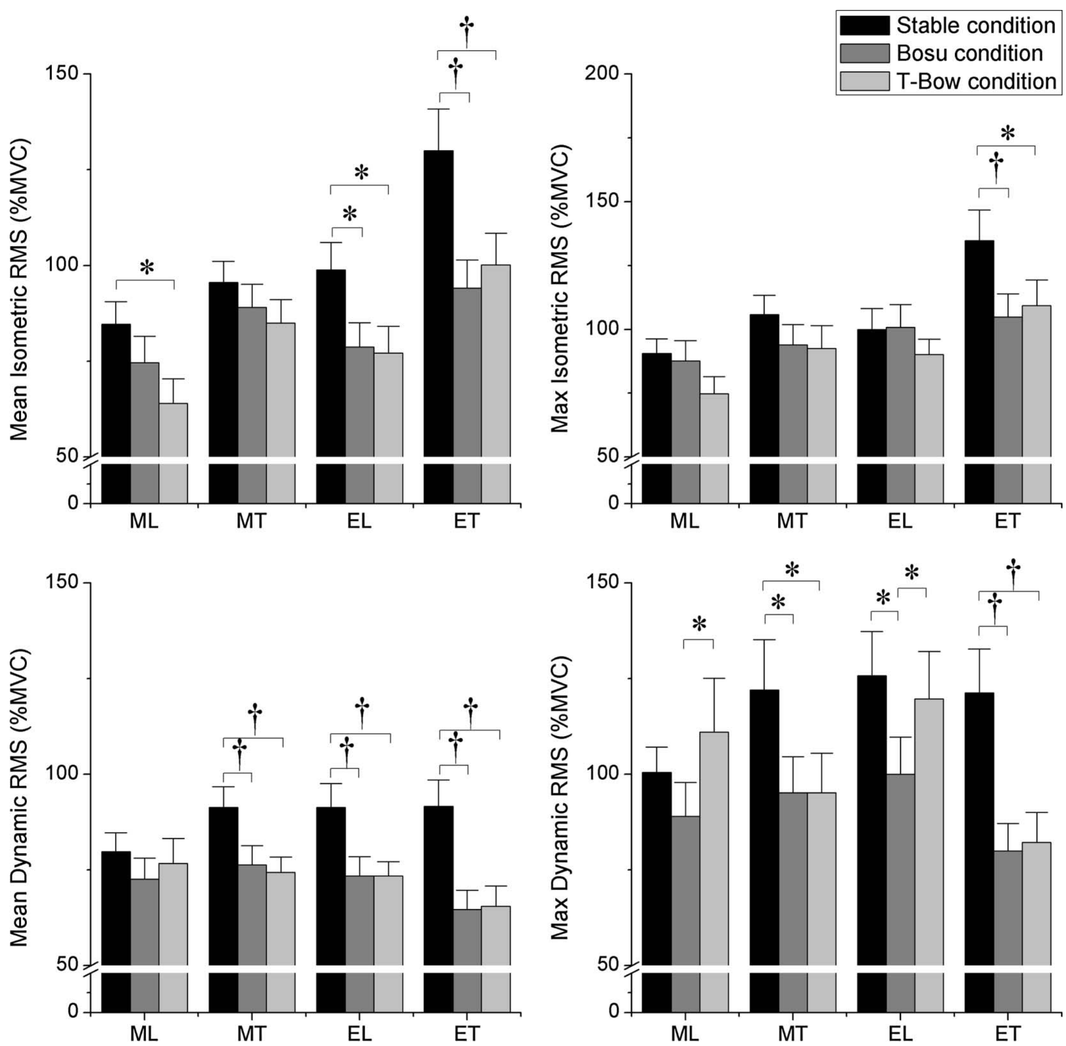

Figure 4. Comparisons between conditions related to the surface electromyography of each tested muscle group. LM = lumbar portion of multifidus spinae, TM = thoracic portion of multifidus espinae, LE = lumbar portion of erector spinae, ET = thoracic portion of erector spinae. Each bar represents the mean, and the error bars the *SEM*. *Significant difference ($p < 0.05$) between groups. †Significant difference ($p < 0.005$) between groups.

The maximum and mean RMSs were selected for every trial. The data obtained were normalized to the MIVC achieved during the back extension exercise and were therefore expressed as a percentage of the back stretch MIVC. Of the force signals obtained, we selected the middle second of the signal and calculated the mean value of this period as a representative value of the maximum isometric force (see Figure 2).

Statistical Analyses

Statistical analysis was carried out using SPSS version 17 (SPSS inc., Chicago, IL, USA). All variables were checked for normality (K–S normality test) and homoscedasticity (Levene's test). Standard statistical methods were used to obtain the mean as a measurement of the central trend and the *SEM* as a measurement of dispersion. A repeated-measures analysis of variance was performed to determine the effect of the condition on the force production. A mixed-model (Muscle Group [LE, TE, TM and LM] × Condition [stable, Bosu and T-Bow]) multivariate analysis of variance was applied to establish the effects of the group and condition over the dependent variables related to the SEMG. The follow-up of the multivariate contrast was performed with univariate contrast. Post hoc analysis with Bonferroni correction was performed in the case of significant main or interaction effects. For all statistical analyses, a $p \leq 0.05$ was accepted as the level of significance.

Results

Isometric Force

There was a main effect of the condition on the maximum isometric force ($F(1.55,46.42) = 56.61$, $p < 0.001$, $\eta_p^2 = 0.65$). In Figure 3, the results of the maximum isometric force provided by the pairwise comparisons are shown. The maximum isometric force achieved when the deadlift was performed in a stable condition was higher than in the other 2 conditions ($p < 0.05$). Moreover, in the T-Bow device trial, the maximum isometric force was larger than in the Bosu condition ($p < 0.001$).

Surface Electromyography

Multivariate contrasts revealed a main effect of the condition ($F(16,105) = 8.56$, $p < 0.001$) on the dependent variables. Moreover, there was a condition × muscle group-interaction effect ($F(48,321) = 1.92$, $p = 0.001$).

A univariate test showed the existence of a main effect of the condition on the maximum isometric RMS ($F(2,240) = 9.64$, $p < 0.001$, $\eta_p^2 = 0.07$), maximum dynamic RMS ($F(1.64,196.8) = 16.14$, $p < 0.001$, $\eta_p^2 = 0.12$), mean isometric RMS ($F(1.82, 218.65) = 24.57$, $p < 0.001$, $\eta_p^2 = 0.17$), and mean dynamic RMS ($F(1.78, 214.23) = 40.49$, $p < 0.001$, $\eta_p^2 = 0.25$). In addition, there was an interaction effect between the different conditions and the muscular group on the maximum dynamic RMS ($F(4.92, 196.8) = 2.92$, $p = 0.015$, $\eta_p^2 = 0.07$), mean isometric RMS ($F(5.47,218.65) = 2.27$, $p = 0.043$, $\eta_p^2 = 0.05$), and mean dynamic RMS ($F(5.36,214.25) = 3.09$, $p = 0.009$, $\eta_p^2 = 0.07$).

Pairwise comparisons (see Table 1) revealed that the maximum isometric RMS, maximum dynamic RMS, mean isometric RMS, and mean dynamic RMS were higher in the stable condition ($p < 0.005$) than in both unstable conditions. Moreover, in the Bosu condition, the maximum dynamic RMS was smaller than in the T-Bow condition.

Furthermore, Figure 4 shows the differences between conditions when muscular group was taken into account. In the maximum dynamic and mean dynamic RMS measured at the TM, LE, and ET, the stable condition showed greater values than in the other 2 conditions ($p < 0.05$). The same occurred in the LE mean isometric RMS and in the ET maximum isometric RMS.

Moreover, the LM showed a larger maximum dynamic RMS in the T-Bow condition than in the Bosu condition ($p < 0.05$). In the isometric tests, the mean RMS in the stable condition was greater than with the T-Bow ($p < 0.05$) in the LM. In addition, it was larger than in the Bosu condition in the ET ($p < 0.05$).

Discussion

The recent inclusion of instability elements in neuromuscular conditioning programs has been substantiated by the ability to generate higher levels of activity in the core (1), mainly shown in analytical exercises for the core (32). The recent popularity of "functional training" has resulted in the incorporation of elements of instability into traditional exercises. The effectiveness of this combination has been questioned for elite athletes (8,11,33,35).

This is the first study that has compared force and myoelectric activity reached during the performance of deadlifts in 3 different conditions of stability, each one representing a different degree of unbalance. This was achieved through the performance of deadlifts in the stable condition, with the use of a T-Bow that causes instability in 1 direction, and with the use of Bosu that causes unbalance in all directions.

Previous studies have shown that, in deadlifting, important paraspinal muscle activation is produced (9,10). In a study by Nuzzo et al. (28), levels of activation of 127.4 ± 12.77 and 124.6 ± 14.57% of MIVC were found for the longissimus and multifidus, respectively, during the performance of deadlifts using a load of 70% of 1RM. We observed activation of 90.52 ± 5.72, 105.78 ± 7.54, 99.91 ± 8.24, and 134.75 ± 11.94% of the MIVC for the LM, TM, LE, and TE, respectively, during the performance of deadlifts with 70% of the maximum isometric force in the stable condition (these data corroborate the major involvement of the paraspinal muscles during deadlifting). Our values are slightly lower, but the fact that the *SEM* is lower in our study suggests that our data could be more representative of the population studied.

Our data reveal significantly decreased force production with increased instability during the execution of the exercise. A reduction in the force reached during the performance of exercises on unstable surfaces has been previously described by McBride et al. (22). They observed a reduction of 45.6% in the force developed during the execution of squats when performed on unstable surfaces (with instability in all directions). Our data confirm this result, because the reduction of maximum isometric force during the execution of deadlifts on the Bosu was 34.19% and on the T-Bow 8.80%. This shows that the force developed is much lower when multidirectional instability devices are used compared to unidirectional ones. Therefore, when strength training is prescribed with the use of devices that generate instability (mainly multidirectional), with the load chosen in relation to the maximum capacity of force generation in the same condition, this can generate a weak stimulus to create adaptations of the agonist musculature because, in reality, appropriate loads are not used for this musculature as a consequence of the instability.

In addition, a higher level of activation of the paravertebral musculature has been obtained under stable conditions than under unstable ones. These differences are more evident when the execution regime of exercises is dynamic. Bressel et al. (4) did not find differences in the level of activation of the spinal erector between the performance of squats on stable surfaces and on the Bosu, with a change of 50% of 1RM in the stable condition. However, the results of our study show a higher activation of the spinal erectors when deadlift were performed on stable surfaces. This discrepancy could exist because the load used in our study was calculated in relation to the maximum isometric force reached in a specific way in each condition. Additionally, some differences appeared that may indicate that using instability devices in 1 direction enables a higher activation of the paraspinal musculature than when using instability devices in all directions. Furthermore, similarly to Willardson et al. (36), an increased risk of injury was detected when carrying out a strength training exercise at an intensity of 70% MIVC on an unstable surface, which can be attributed mainly to losses of balance.

One of the principal limitations of this study is that there was no synchronization between the acquisition of registers of force and of SEMG. If these registrations had been performed, the analysis and the data reduction could have been performed more precisely, using the same time frame for the analysis of both signals. Another important limitation was produced as a consequence of trying to control the cadence of the execution during the exercises with instability. In some cases, the subjects were unable to follow the rhythm precisely because they needed to complete the movement with a higher or lower speed for the purpose of maintaining balance.

This is the first study that compares 3 levels of instability for the same exercise with the same load, and the data suggest a relationship between the level of instability and the levels of muscle activity and force production. Therefore, the use of instability devices to increase the stimulus on the stabilizing musculature of the abdomen region in healthy people is questionable. However, it would be interesting to see whether future studies observe differences in the function of agonist muscles depending on the level of instability generated by these devices.

Taken together, our data indicate that the execution of deadlifts in unstable conditions decreases physical performance and generates a lesser stimulus on the paravertebral musculature than the same exercise performed in stable conditions. In addition, it seems that the number of directions in which the device produces instability could also determine the level of activation reached, with the achievement of higher activations when instability is produced in a single direction.

Practical Applications

The inclusion of deadlift in a program of neuromuscular training guarantees high levels of functionality without the necessity of adding instability elements, thus favoring a corporal position technically safer to the rachis. This implies that instability devices may not be necessary to improve core stability training, so long as individuals perform upright, resisted, dynamic exercises. Therefore, it may be recommended not to use unstable surfaces as part of an overall athletic development plan. Because using unstable surfaces in training with loads >70% 1RM would not be effective in strengthening core stability, they should also not be used in recreational and fitness-oriented neuromuscular conditioning.

However, if the decision is eventually made to use unstable surfaces during parts of the season that do not require high levels of intensity, it is important to know which type of instability element to select, because the capacity to build up strength and muscular activity will depend on degrees of instability caused by the device. Training using materials that cause imbalances on 1 movement axis could have greater intensity than training using materials that cause imbalances in 2 directions.

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