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Electromyographic Activity of Lower Body Muscles during the Deadlift and Still-Legged Deadlift

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ABSTRACT

Bezerra ES, Simão, R, Fleck SJ, Paz G, Maia M, Costa PB, Amadio AC, Miranda H, Serrão JC. Electromyographic Activity of Lower Body Muscles during the Deadlift and Still-Legged Deadlift. **JEPonline** 2013;16(3):30-39. The purpose of this study was to analyze eletromyographic (EMG) signal of biceps femoris (BF), vastus lateralis (VL), lumbar multifidus (LM), anterior tibialis (AT), and medial gastrocnemius (MG) during the deadlift (DL) and stiff-legged deadlift (SLDL). Fourteen men (26.71 ± 4.99 yrs; body mass 88.42 ± 12.39 kg; 177.71 ± 8.86 cm) voluntarily participated in this study. The data were obtained on three non-consecutive days separated by 48 hrs. In the first day, anthropometric measures and the repetition maximum testing (1 RM) for both exercises were applied in a counter-balanced cross-over design. On the second day, the 1 RM was re-tested. On the third day, both exercises were performed at 70% of 1 RM and the EMG data were collected. Parameters related to the RMS during the movement, temporal activation patterns, and relative times of activation were analyzed for each muscle. The maximum activation level for VL during the DL (128.3 ± 33.9% of the EMG peak average) was significantly different (P = 0.027) from the SLDL (101.1 ± 14% of the EMG peak average). These findings should be useful when emphasizing different muscle groups in a resistance training program

Key Words: Resistance Training, Electromyography, Muscle Strength

INTRODUCTION

The deadlift (DL) and variations are usually prescribed by strength and conditioning professionals to strengthen the legs, hips, back, and torso musculature (6). The traditional DL begins with the knees flexed in a squat type position. The elbows are extended and an alternating handgrip is used to grip the bar, which is positioned over the metatarsal region of the lifter's feet. During the concentric exercise movement, the bar is raised from the floor to a mid-thigh position by extending the hip and knee joints (8). In the stiff-legged deadlift (SLDL), the concentric phase begins with the knees almost completely straight and the bar is moved from the floor to a mid-thigh position mainly by hip extension keeping the knees slightly bent throughout the exercise movement.

Studies have compared the DL and the Sumo style deadlift using 3D kinematic analysis (10) and 2D kinematic analysis (18). Kinematic analysis has also been used to compare DL technique of skilled and unskilled lifters (4). Although several studies have examined the DL, only a few researchers have investigated muscle activation during this exercise (5-8). The DL and Sumo technique have been compared using electromyography (EMG) analysis. The data indicate that the vastus lateralis, vastus medialis, gastrocnemius (medial head), and tibialis anterior showed greater muscle activation during the Sumo style compared to the DL (9).

The SLDL has been compared to the leg curl (LC) and back squat (BS) using EMG techniques (19). The results indicate that greater muscle activation of the biceps femoris (long head) and the semitendinosus muscles takes place in each of the exercises during the concentric phase compared to the eccentric phase. There were differences among the three exercises, with the LC and the SLDL demonstrating greater biceps femoris and semitendinosus muscle activation *vs.* the BS exercise (19). However, there is a lack of evidence to compare muscle activation between the DL and SLDL. Such information may help coaches and strength and conditioning practitioners to optimize the resistance training prescription, and also specify the performance of a target muscle during the execution of an exercise. Thus, the purpose of this study was to analyze the EMG signal of biceps femoris (BF), vastus lateralis (VL), lumbar multifidus (LM), anterior tibialis (AT), and medial gastrocnemius (MG) during the DL and SLDL.

METHODS

Subjects

Fourteen men (26.71 ± 4.99 yrs; 88.42 ± 12.39 kg; 177.71 ± 8.86 cm; biacromial diameter 42.44 ± 2.46 cm; and bi-trochanteric diameter 44.54 ± 5.44 cm) voluntarily participated in the study. All subjects had at least 2 yrs of recreational resistance training experience, no current injury to the lower extremities, and experience in both the DL and the SLDL resistance exercises. Following an explanation of the experimental procedures, the subjects read and signed an informed consent form. This study was approved by the research ethics committee.

Procedures

To investigate muscle activation of selected lower body muscles during the DL and SLDL, data were collected on three nonconsecutive test days. Forty-eight hours was chosen as the time period between the 3 tests sessions as this is the minimum rest period needed to recovery between one repetition maximum (1 RM) attempt (17). On the first test day, anthropometric measurements and the 1 RM for both exercises were determined in a counter-balanced cross-over design. On the second test session, the 1 RM was re-tested. On third test session, both exercises were performed with 70% of 1 RM and EMG data were measured for the BF, VL, LM, AT, and MG. Three repetitions using 70% of the 1 RM was used as the percentage of 1 RM during collection of EMG data because it is often used when performing resistance training (8,19). On third test session, 20 min of rest were provided between the exercises (which were performed in a crossover design manner).

1 RM Test

The mass of all weight plates and bar (Buick®, São Paulo, SP, Brazil) used for measuring 1 RM were determined with a precision scale. The data were assessed on two non-consecutive days, separated by 48 hrs in a counter-balanced cross-over design. To minimize possible errors in the 1 RM tests, the following strategies were adopted: (a) all subjects received standard instructions before testing on the general routine of data assessment and the exercise technique of each exercise; (b) the exercise technique of subjects during all testing sessions was monitored and corrected as needed; and (c) all subjects were given verbal encouragement during the tests. Each subject's 1 RM was determined with a maximum of five 1 RM attempts for each exercise and 3 to 5 min rest intervals between attempts. After the 1 RM for either the DL or SLDL was determined, a 10 min rest period was provided before the first 1 RM for the second exercise was performed. Standard exercise techniques were followed for both exercises. No pause was allowed between the eccentric and concentric phases of a repetition. In addition, for a repetition to be successful, a complete range of motion as is normally defined for the exercise had to be completed.

Maximum 1 RM tests were determined on 2 d separated by a 48-hr interval in order to determine test-retest reliability. The subjects were not allowed to perform any exercise other than normal daily activity during the period between the testing sessions. Excellent day-to-day reliability for each 1 RM exercise was shown by this protocol. The 1 RM testing on the two occasions showed intraclass correlation coefficients of $r = 0.96$ and $r = 0.94$ ($P<0.05$) for the DL and SLDL, respectively. Additionally, the *t* tests revealed no significant difference between the 1 RM tests for either of the exercises.

Characterization of the Movements Analyzed

The DL can be characterized with the barbell initially on the floor. The subject starts the exercise movement with ~90° knee angle with the thigh parallel to the floor. The bar is grasped with an alternating handgrip. The hips are flexed with the torso close to 45° from vertical with the scapulae partially abducted. The hands are placed on the bar at approximately biacromial breadth apart. During the concentric phase of the movement, the bar passes the shins while the hips and knees extend. The trunk is raised to an upright standing position while the scapulae are adducted. The concentric phase is complete once the upright position is achieved. The eccentric phase is performed by returning the bar to the floor with all joint movements performed in reverse order. In the SLDL start position the barbell is on the floor, the feet are spread to approximately bitrochanteric width, knees are slightly flexed, shoulders are in a neutral position, scapula adducted, and hands are holding the bar with an alternating grip at approximately biacromial breadth. During the concentric phase, the bar passes the shins, while the hips extend, raising the trunk to an upright standing position while extending the shoulders and adducting the scapulae. The concentric movement is completed once the upright position is achieved. The eccentric phase is performed by returning the bar to the start position with all joint movements performed in the reverse manner compared to the concentric phase.

Electromyographic and Kinematic Data

To examine muscle activity, surface electromyography signals were collected from the muscles to be analyzed (EMG 1000, Lynx Inc. São Paulo, São Paulo, Brazil). Pre-amplified active electrodes, with a 20 times gain, band pass up to 4 KHz set on a polyurethane structure with two silver plates positioned 10 mm apart were used for all analyses of the muscles examined. Before the application of the electrodes, the skin was shaved, abraded, and cleansed with alcohol. The electrodes were then placed between the motor point and the distal tendon in each muscle studied in the direction of the muscle's fibers (14).

For the assessment of the kinematic data, spherical plastic markers (2.5 cm in diameter) covered with reflective tape were positioned over the following bony landmarks: lateral malleolus of the right ankle, proximal upper edge of the lateral tibial plateau of the right knee, greater trochanter of the right femur, and lateral acromion process of the right shoulder. In addition, a piece of reflective tape (1 cm^2) was positioned on the third metatarsal head of the right foot. Data were collected at 30 HZ using a video camera (SONY®, São Paulo, São Paulo, Brazil) during the performance of each exercise. The images were analyzed using a Vicon Motion Analysis System (Vicon Corporation, Los Angeles, CA, USA). The beginning and ending position of the eccentric and concentric phase for both exercises was determined with the hip flexed to its greatest extent during the exercise movement. Hip angle was defined as 0° in the fully flexed hip position.

EMG Analyses

The EMG of the BF, VL, LM, AT, and MG muscles were analyzed during the DL and the SLDL. These muscles were chosen because they are superficial and biomechanically involved in the exercise movements (1,8,19). Although the LM is regarded as a deep muscle in the lumbar region, it is slightly more superficial and can be located by palpation of the spinous process of the 5th vertebra [1]. All EMG signals were recorded at a sample frequency of 1000 Hz. For each muscle, temporal activation patterns, muscle activation level, and contraction time were analyzed. Temporal activation patterns were obtained using a linear wrap trace from the results of the EMG signal of each muscle after normalization. Muscle activation level was obtained using the Root Mean Square (RMS) measure. The RMS represents the greatest value obtained during the movement [15]. For the relative time of activation, a time interval was determined for each muscle in which muscular activity was maintained at a level over 50% of the peak EMG signal during the movement cycle including both eccentric and concentric phases. The relative time of activation was expressed as a percentage representing how long the EMG was above at least 50% of the peak EMG during the temporal activation patterns (movement cycle) of each exercise.

The original signal of each muscle was smoothed using a butterworth filter (second order butterworth low pass filter with a frequency of 500 Hz). After filtering, normalization of the EMG signal was performed using the peak average for each muscle in three repetitions of the DL or SLDL. Briefly, the maximum EMG value for each muscle was determined for each movement cycle, an average was calculated, and then a peak muscle activation value for each subject was calculated. This value was used as a reference value for 100% muscle activation. Thus, the entire signal was normalized using this value that allowed for comparison among the different muscle groups, exercises, and subjects. After normalization, the starting and ending points for each of the three repetitions were determined and then, subsequently, the average EMG calculated. The muscle activation intensity value represented by the muscular intensity estimation (RMS) was obtained from the original signal. For normalization, RMS, and the relative time of activation of each muscle, an EMGONIO1 routine was used (MATLAB 6.0 software; MathworksInc, Natick, Massachusetts, USA). The ORIGIN 6.0 software (Microcal Software Inc, Massachusetts, USA) was used for graphic representations.

Statistical Analysis

The data were descriptively analyzed in which the mean and standard deviation for each dependent variable were calculated. Data normality was checked using the Shapiro-Wilk test. The *t* test for paired data was used to determine significant differences in maximum RMS and relative activation time of muscles between the DL and SLDL exercises. The alpha level was set at $P<0.05$ for all analyses. All statistical analyses were performed using SPSS 20.0 software for Windows (SPSS Inc., Chicago, IL, USA).

RESULTS

Comparisons of RMS revealed significant differences ($P<0.05$) between the DL and the SLDL for the VL and MG muscles. However, no differences were found for the BF, LM, and AT muscles (Table 1). Relative time of activation between the DL and the SLDL showed significant differences for the VL only ($P<0.05$). No significant differences were found for the others muscles (BF, LM, AT, and MG) (Table 1).

Table 1. Mean ±SD of EMG Variables Analyses.

	DL		SLDL		
RMS	**Mean**	**±SD**	**Mean**	**±SD**	**P**
BF	100.1	24.7	98.6	28.5	0.699
VL	128.3*	33.9	101.1*	14.6	0.027
LM	112.7	42.7	106	20.5	0.609
MG	103.8*	12	108.3*	16.3	0.012
AT	104	18.8	109.2	15.3	0.130
	DL		**SLDL**		
EMG/TIME	**Mean**	**±SD**	**Mean**	**±SD**	**P**
BF	32.00	16.66	31.08	23.86	0.890
VL	43.42*	18.85	21.11*	14.71	0.026
LM	10.53	5.85	20.41	18.83	0.109
MG	50.99	27.49	29.80	16.63	0.088
AT	40.43	35.16	37.83	38.61	0.709

RMS: Percentage normalization of the EMG peak average; **EMG/TIME:** relative time activation as percentage of movement cycle above 50% of RMS; **BF:** biceps femoris; **VL:** vastuslateralis; **LM:** lumbar multifidus; **MG:** medial gastrocnemius; **AT:** anterior tibialis; **DL:** Deadlift; **SLDL:** Still-legged deadlift. ***Significant differences between the DL and the SLDL ($P<0.05$).

The temporal activation between the DL and SLDL for the BF, LM, MG, and AT muscles demonstrated similar patterns. However, the VL muscle showed a different activation pattern. During the DL, the VL showed higher activation at the beginning of the ascent and ending of the descent phases. In contrast, during the SLDL, the VL showed its highest activation at ~60° of ascent phase (Figure 1).

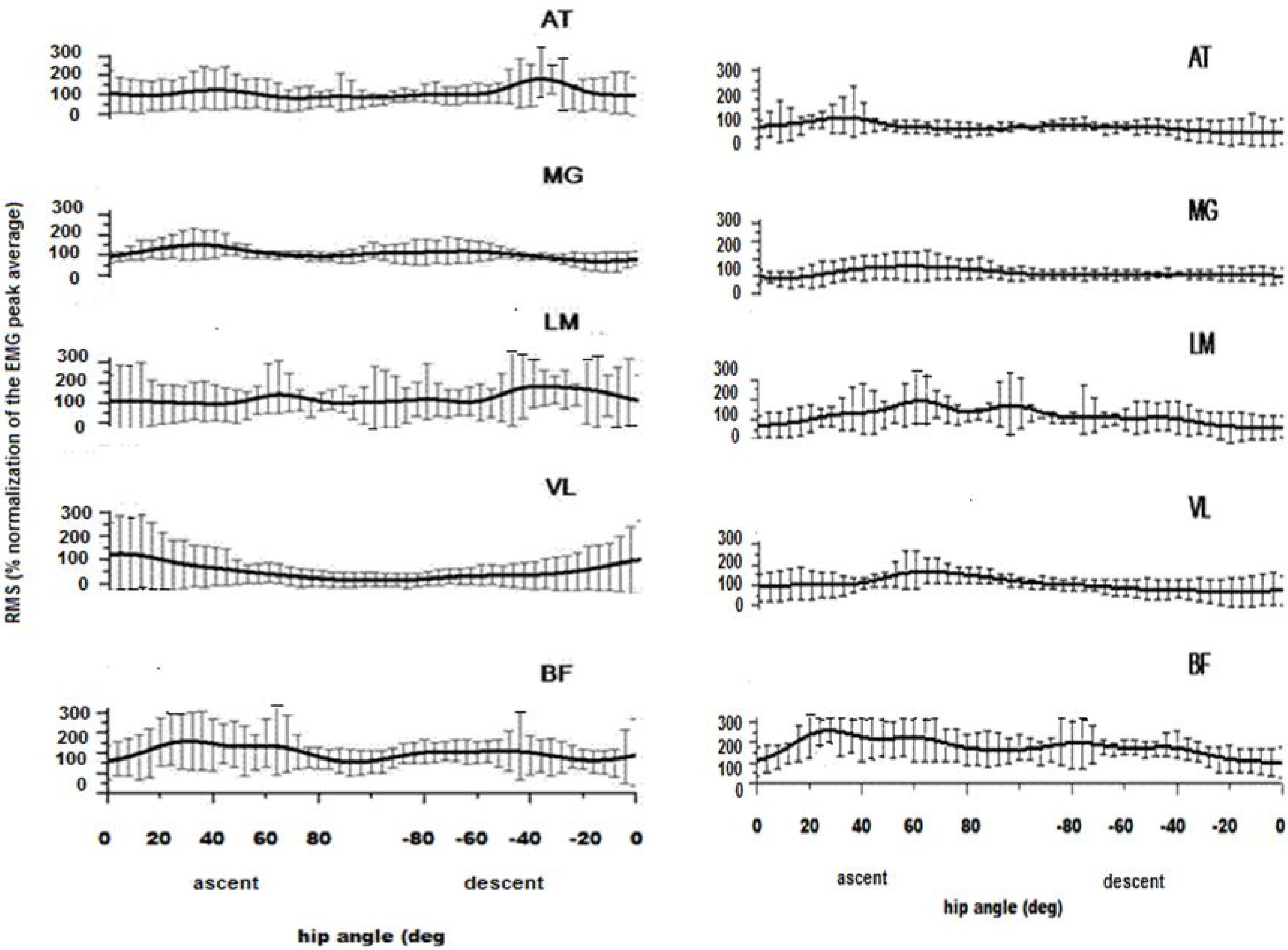

Figure 1. Mean ±SD of the RMS for the Analyzed Muscles. BF: biceps femoris; VL: vastus lateralis; LM: lumbar multifidus; MG: medial gastrocnemius; AT: anterior tibialis; DL: Deadlift; SLDL: Still-legged deadlift. *Significant differences between the DL and the SLDL ($P<0.05$).

DISCUSSION

The key findings of this study were the differences in RMS for the VL and MG muscles between the DL and SLDL exercises. In addition, the VL demonstrated a higher relative activation time (i.e., time above 50% RMS) than the other muscles during the DL. The VL muscle had a peak of activity during the first 20° of the ascent phase due to its role in knee extension and indirectly hip extension (in that the movement is a closed kinetic chain exercise). This finding is consistent with results from the parallel squat (2), mini-squat (6), leg press, squat, and deadlift (8,11); all demonstrated an increased level of activity in the VL muscle in the beginning of the concentric phase.

The changes in the VL muscle EMG potential during the DL may be associated with its role during knee joint extension (ascent phase) and flexion (descent phase) of the DL movement and the concomitant decrease of motor units used at the same resistance during the descent phase of the movement. The percentage of activity in the data presented in this study is greater than reported by Gullett and colleagues (12), who analyzed the differences in EMG activity of lower limb muscles as a function of bar position (front or back to the trunk) in the squat exercise. In the Gullet et al. study (12), the VL muscle activation was 60% of maximal voluntary isometric contraction (MVIC). However, it is noteworthy that the forms of normalization of EMG signals were different, since the aforementioned study used MVIC.

Proposed Mechanisms to Explain the EMG Activity

In the descent phase of the DL (between -40° to 0°), the RMS signal for the VL also increased but not to the extent as it did in the ascent phase. The gradual increase of this muscle's activity is due to the changing need to exert more strength by the time the knee flexion becomes more acute during the descent phase of the DL movement. Similar findings were noticed by Escamilla et al. (8,9) and Gullett et al. (12) during the squat and the conventional style DL. The VL RMS during the SLDL showed a constant activity during the descent phase of the movement (between -80° and 0°). However, it shows an activity peak between 40° and 60° in the ascent phase of the SLDL movement, possibly due to the factors of needing to increase the muscle activity at this knee angle of the movement and to counteract the co-contraction of the long head of the BF that has an increased muscle activity during the same movement phase. The increased VL RMS may also be essential for knee joint stabilization, but more research is needed to confirm this point.

The MG activity during the DL and SLDL exercises increased slightly during the ascent phase. The increased MG activity during the ascent phase could be explained by an increased plantar flexion moment during this phase as shown by Escamilla et al. (2000) for the conventional style DL. Da Silva et al. (5) found that the gastrocnemius muscle is more activated during leg press exercise with low foot placement and 45° (near 80% of MVIC). This may have happened due to the increased plantar flexion movement in the two exercises. However, the RMS showed significant differences with the SLDL that may be attributed to the initial imbalance of the body caused by not bending the knee, which required a greater involvement of stabilizing muscles with MG.

The BF behavior during the DL showed a muscle activity peak in the beginning of the ascent phase between 20° and 40° of hip extension followed by a decrease in the last degrees (-20°) of movement during the descent phase (hip flexion). However, this factor may not be attributed to a reduction of muscle activation in the descent phase, since as previously shown, at the same force output eccentric actions compared to concentric actions involve a smaller activation of motor units and, therefore, a decrease in the EMG amplitude. The RMS average observed for BF during the initial ascent phase of the DL is due to the role it muscle plays during hip joint extension. These findings were similar to Escamilla and colleagues (9) who observed that for DL the movement during the execution of the technique variations (e.g. sumo and conventional) and during movements such as the squat showed higher muscle activity of BF during hip joint extension (19). During the SLDL, the BF showed the same behavior as during the DL, with a peak of muscle activity in the ascent phase between 20° and 40° during hip extension. Similar results were observed for DL, it was showed also a decreasing in BF activity in the descent phase (-80° to -20° of the movement) while the hip joint flexion was performed. The behavior of the BF during the DL and the SLDL in ascent and descent phases were similar and may be attributed to its role during both flexion (descent phase) and extension (ascent phase) of the hip joint during the exercise movement.

Synergist Muscle Behavior during the Resistance Exercises

The findings of this study disagree with the findings of the Yamishita (20) study, who suggested that agonist-antagonist concurrent activation may generate an inhibition in the activation of the muscles.

This hypothesis indicated that the single-joint exercise such as the SLDL may provide an increase in hamstring muscle activity. Wright et al. (19) also observed that squat promoted less muscle activation of BF and semitendinosus when compared to LC and SLDL. These studies are also in contrary to the results found by Luttgens and Wells (16), who did not observed any significant difference in the hamstring activity during hip and knee extension.

The LM activation during the DL and the SLDL may be characterized as a normal pattern of muscle activity, since little variation was showed during the ascent and descent phases of the movements. Similar results were observed by Escamilla et al. (9) for the sumo and conventional style deadlift. Despite kinematic differences caused by an increased forward flexion of the trunk during the conventional DL, variations regarding muscle activity of the LM did not occur, indicating that the action of the LM does not change significantly during the DL. Hamlyn et al. (13) found that the erector spine muscles in the lumbosacral region showed an increase of 34.5% in muscle activity while performing a squat compared to the DL.

Although in the current study, there were no significant differences between the two movements. It is noteworthy that the muscle activity was high (i.e., above 80% of MVIC) (3), which may indicate a high stabilizing effect. The AT muscle activity remained constant at a low intensity during the DL and SLDL. Relative time of activation showed high standard deviation values indicating a high variation among subjects for both exercises, which indicates individual technique may be a factor that affects muscle activity during the DL and SLDL.

Limitations and Implications

One of the limitations of the current study is that only one set of each exercise was performed. A traditional resistance training session is composed by multiple sets and exercises. Also, the relative time of activation may be influenced by the subjects' resistance training experience. However, in the current study all subjects had at least 2 yrs of resistance training experience with the DL and SLDL exercises. This suggests that other factors may be responsible for the relative time of activation such as the number of sets, loads, and velocity. The BF and AT showed a similar mean relative time of activation for both the DL and SLDL. The VL and MG had higher mean relative time of activation during the DL while the LM had a higher mean during the SLDL. The lack of agreement in the scientific literature related to muscle relative time of activation in dynamic movements (including the DL and SLDL) is a limitation, which make the comparison between the exercises difficult. Thus, in future studies other variables should be evaluated such as the influence of number of sets, exercise velocity, load intensity and muscle groups in the muscle activation and relative time activation during back squat exercises.

CONCLUSIONS

The EMG data indicate that the DL is more effective for activating the VL muscle than the SLDL. However, the MG muscle showed higher muscle activation during the SLDL than the DL. These findings should be useful when emphasizing different muscle groups in a resistance training program.

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