

DIFFERENCES BETWEEN CONVENTIONAL AND SUMO VARIANTS OF DEADLIFTING: KINEMATIC, KINETIC AND ELECTROMIOGRAPHIC STUDY

Mihajlo Jovanović¹, Marko Kapeleti¹, Miloš Ubović¹, Nemanja Pažin²,
Duško Ilić³, Vladimir Mrdaković³

¹ PROFEX - Academy of Healthy Living, Belgrade, Serbia

² Faculty of Sports Management, Alpha University, Belgrade, Serbia

³ Faculty of Sport and Physical Education, University of Belgrade, Serbia

Abstract

Deadlift is a measure of the overall strength of the whole body and it is one of the three exercises in the powerlifting competition. There are conventional and sumo variant of deadlift. The aim of this study was to determine the differences between the two lifting techniques from the aspect of kinematics, kinetics and electromyography. Nine physically active men, average age 29.1 ± 3.3 years, body height 181.0 ± 1.0 cm, body weight 82.3 ± 13.3 kg and body mass index 25.0 ± 3.8 kg/m² were recruited for this study. Each subject lifted weight close to his own body weight with three repetitions, in three series, for each of the techniques. The speed of one lift was 3 seconds for each of the phases (concentric and eccentric). The angles and amplitudes for the following figurative points were monitored: trunk in relation to the horizontal plane (angle), center of the hip joint and center of the knee joint in the "liftoff" (LO – position in which the weight separates from the ground) and "knee passing" (KP – position in which the weight passes in front of the knee position), i.e. in the liftoff-knee passing (LO-KP), knee passing-lift completion (KP-LC; LC – final, i.e. completely upright body position) and liftoff-lift completion (LO-LC) phase. The mechanical work was monitored as a one of the kinetic variables. Electromyographic activity was monitored for the following muscles: *m. vastus medialis*, *m. vastus lateralis*, *m. rectus femoris*, *m. gluteus maximus*, *m. erector spinae* (L3-L4), *m. semimembranosus* and *m. biceps femoris caput longum*. The monitored electromyographic variable was the average normalized amount of muscle activation in relation to maximal voluntary contraction, for all 18 individual deadlift repetitions (3 series \times 3 repetitions \times 2 techniques). One-way analysis of variance with repeated measurements (for the amount of muscle activation and performed mechanical work) and two-way analysis of variance with repeated measurements (for angles and amplitudes) were used for statistical data processing. Significant differences were found between techniques in the initial angular positions in all monitored joints ($p < 0.05$), except for the angle in the knee joint where the trend was observed ($p = 0.0996$), as well as in the transit position for the trunk angle relative to the horizontal plane and angle at the hip joint ($p < 0.05$). There was a statistically significant difference between techniques in amplitudes in the hip joint during KP-LC phase ($p < 0.05$) and total amplitude ($p < 0.05$), as well as in the knee joint during LO-KP phase ($p < 0.05$) and total amplitude in the form of a trend ($p = 0.0996$). The performed mechanical work is significantly higher when lifting the load with the conventional deadlift technique (DL_{con}) ($p < 0.05$). Activation of medial and lateral heads of *m. quadriceps femoris* is significantly higher ($p < 0.05$) when lifting with sumo deadlift technique (DL_{su}). It was noticed that activation of postural muscle groups (*m. erector spinae*, *m. gluteus maximum*, *m. semitendinosus* and *m. biceps femoris caput longum*) is higher when lifting the load with DL_{con}, but not significantly ($p > 0.05$).

Keywords: MUSCLE ACTIVATION / MECHANICAL WORK / JOINT ANGLES / STRENGTH TRAINING

Correspondence with the author: E – mail: mixajlo.jova@gmail.com

INTRODUCTION

One of the most applicable exercises for improving absolute power, power in speed, rate of force development and trunk stability is the "deadlift" exercise. Deadlift can be a measure of general strength, maximum or repetitive strength of the whole body and it is one of the three exercises in powerlifting competition (McGuigan & Wilson, 1996). The goal of this discipline is to lift as much weight as possible, and it also includes the exercises like "squat" and "bench press". Some of the benefits of using this exercise are improved joint stability, better performance of sports skills and the development of overall strength and power (Mannie, 1997).

The two most popular variants of the deadlift are sumo (DL_{su}) and conventional (DL_{con}). DL_{su} is described as a variant with a wide stance, a divergent foot position with extended arms holding the bar between the knees (Piper & Waller, 2001). In DL_{con} the stance position is shoulder-width apart, while the extended arms hold the bar on the outside of the knees.

So far, a large amount of research has been conducted on the subject of differences between different variants of deadlifting. Namely, the differences between DL_{con} and the "romanian" variant of the deadlift (Lee et al., 2018), and the differences between the DL_{con} and the deadlift variant with fully extended knees (Bezerra et al., 2013) were examined. Also, the group of authors studied the differences between the DL_{con} with the Olympic and hexagonal bar (Andersen et al., 2018, Camara et al., 2015, Lake et al., 2017, Swinton et al., 2011). The differences between deadlifts with different grips (Krings et al., 2019), comparisons between deadlifts with front and back squats (Korak et al., 2018, Hamlyn et al., 2007), and differences between classic deadlift and deadlift with added chains (Nijem et al., 2016) were also examined.

One study examined the kinematic differences between front and back squats and DL_{con} and DL_{su} (Kasovic et al., 2019) on 24 men and women. The variables were average speed of concentric contraction (SCC), peak speed of concentric contraction (PCC), and linear weight path (LWP). The results obtained show that at all load levels (from 30% to 100% of 1RM with an increase of 10% per series) LWP was higher in DL_{su} . SCC differed significantly at 80–89% 1RM, 70–79% 1RM, and 40–49% 1RM. In accordance with these findings, it was suggested to determine the individual profiles of the relationship between weight and lifting speed, both for the front and back squats, and for the conventional and sumo variants of deadlift.

According to another study that examined the kinematic differences between DL_{con} and DL_{su} (McGuigan & Wilson, 1996), it was claimed that in the "liftoff" position (LO – the position in which the weight separates from the ground), the angle at the knee joint is larger in DL_{con} . On the other hand, the trunk makes a larger angle with the horizontal in the DL_{su} , as well as the angle at the hip joint. From the LO to the "knee passing" position (KP – the position in which the weight passes in front of the knee) in DL_{con} , a higher amplitude of trunk extension was measured in comparison to DL_{su} . Also, many authors (Cholewicki et al., 1991, McGuigan & Wilson, 1996, Escamilla et al., 2000) obtained results in which the trunk forms a significantly smaller angle with the horizontal in the DL_{con} in comparison to the DL_{su} , at the LO position.

The wider stance position in the DL_{su} made the weight distance traveled to be significantly smaller, and thus also the mechanical work. According to related researches (Escamilla et al., 2001) on the study of the biomechanical characteristics of DL_{su} and DL_{con} , it was found that the vertical weight distance traveled, normalized to height of the subjects, was 20-25% higher in MD_{con} in comparison to DL_{su} , from LO to "lift completion" position (LC – final, completely upright body position). Based on that, the mechanical work done was 25-30% higher using DL_{con} .

In the literature exists another research with the aim of examining the differences between techniques in terms of electromyographic activity (Escamilla et al., 2002). They studied the activation of the lower leg and upper leg muscles, extensors in the hip joint and spine extensors. According to results, only *m. vastus lateralis* and *m. vastus medialis* achieved statistically significant higher activation during DL_{su} , while during DL_{con} extensor muscles in the hip joint and spine extensors were more active but without statistically significant differences. In summary, DL_{con} has a stronger motor recruitment of the posterior chain (*m. biceps femoris caput longum*, *m. semitendinosus*, *m. gluteus maximus*, *m. erector spinae*), while the load in DL_{su} is mainly transferred from the lower back to *m. quadriceps femoris* (Escamilla et al., 2002).

In relation to all the above studies and the variables used in them, the aim of this research is to examine the kinematic, kinetic and electromyographic differences between the conventional and sumo variants of deadlifting technique, assuming that there are significant differences in individual variables. In other words, the purpose of this research is to comprehensively describe two lifting techniques and to define how each of the techniques affects the muscles engagement of the locomotor system. Theoretical significance of this paper is a contribution to previous researches that has dealt with this issue, while the practical significance of this paper is the possibility of choosing one of the techniques for specific tasks in the sports training process or recreational exercise.

METHOD

Research protocol

The research was conducted in the training and diagnostic center "PROFEX – Academy of Healthy Living" in Belgrade. The research protocol consisted of introducing the research goals and tasks to the subjects, followed by the basic anthropometric and morphological measurement, warm-up and preparation of the locomotor system, familiarization with the testing protocol and testing, i.e. sampling of kinematic, kinetic and electromyographic variables during lifting with DL_{con} (Figure 1) and DL_{su} technique (Figure 2). All procedures were performed on the same day.



Figure 1. Deadlift – Conventional technique at LO, KP and LC position.



Figure 2. Deadlift – Sumo technique at LO, KP and LC position.

Subjects were instructed to arrive without food and water consumption for at least one hour prior to testing, and not to have intense physical activity that day.

Basic anthropometric and morphological measurement included the measurement of body height, body mass and body mass index. Body height [m] was measured using a digital altimeter BSM170 from the Arab Engineers company and body weight [kg] using an InBody770 digital scale from South Korean InBody company. Body mass index [kg/m^2] was obtained by dividing mass [kg] by the square of height [m^2].

The warm-up procedure of the locomotor system was performed on the treadmill for 6 minutes. Subjects walked at the first and last minute at the speeds between 5.5 and 6.0 km/h, while in the meantime, they ran at the speeds between 11 and 13 km/h.

The general preparation of the locomotor system, following the basic principle of the exercise sequencing – "from head to toe", was consisted of static and dynamic stretching and muscle toning for 8 minutes.

Within the familiarization with the testing protocol, the subjects were informed in detail with the requirements of the proper deadlift technique – simultaneous extension in the knee and hip joint, forced abdominal contraction, exhalation during weight lifting, constant maintenance of neutral spine position, controlled movement duration in one direction for 3 seconds, maintenance of upright posture and controlled lowering of the weight on the ground after each repetition. The weight used was 20 kg (Olympic bar).

The specific preparation of the locomotor system involved deadlifting, primarily with the weight reduced by 20 kg, and then by 10 kg from the one that was used during main testing. The number of repetitions was decreasing – first 8 and then 6, respectively for each of the serial. The preparation was done first with DL_{con} , and then with DL_{su} technique.

The short relaxation procedure involved thigh relaxation, as well as passive stretching of the *m. quadriceps femoris* and hamstrings. The duration of this procedure was 3 minutes.

The testing protocol involved sampling of kinematic, kinetic and electromyographic variables according to the established procedure. The protocol included the placement of electrodes, measurement of the maximal voluntary activation of muscles whose electromyographic activity was monitored during the main testing, and placement of markers for movement tracking.

The measurement of maximal voluntary activation was performed according to previous recommendations of the available literature (Criswell, 2010; Barbero et al., 2012). The electrodes were placed on the muscle belly and in the direction of muscle fibers path. The electrodes are fixed using adhesive tape. Firstly, a gradual increase in the voluntary effort for 2-3 seconds was required from subjects. Then, the application of the maximal manual external resistance was required for 5 seconds and finally a gradual decrease in the voluntary effort and manual external resistance for 2-3 seconds.

The electromyographic activity of the following muscles on the right side of the body was analyzed: *m. erector spinae (L3-L4)*, *m. gluteus maximus*, *m. vastus medialis*, *m. vastus lateralis*, *m. rectus femoris*, *m. biceps femoris caput longum* and *m. semitendinosus*. For the analysis of kinematic and kinetic variables, "X" markers shape were placed on the following sites: center of bar, ankle joint, knee joint, hip joint and shoulder joint. Markers are placed on the left side of the body.

The weight for each subject was approximately the same as the body weight of the subject itself. The number of series and repetitions within the series was 3. The application of DL_{con} and DL_{su} technique alternated after each serial. The technique involved lifting the load from the LO, through the KP, to the LC position. The duration of the concentric and eccentric phases was 3 seconds each with the 3-second pause between. The pause between series was 2 minutes. Criteria for the proper deadlifting technique were all the key details listed in the familiarization of the subjects with the testing protocol. The long relaxation procedure involved detailed stretching and ice frictional massage of the leg muscles. The duration of this procedure was 10 minutes.

Subjects

The sample of subjects consisted of 9 physically active males. The basic age, anthropometric and morphological characteristics can be seen in Table 1.

Table 1. Age, anthropometric and morphological characteristics of the subjects (n = 9) presented with the mean value, standard deviation and coefficient of variation.

	Age	BH [cm]	BW [kg]	BMI [kg/m ²]
Mean	29.1	181	82.3	25.0
Standard deviation	3.3	1	13.3	3.8
Coefficient of variation [%]	11.2	2.9	13.3	15.2

Note: BH – body height; BW – body weight; BMI – body mass index.

Table 1 shows that the sample of subjects is extremely homogeneous in its basic age, anthropometric and morphological characteristics, which justifies their usage for the purpose of this research.

Sample of variables and method of their measurement

Kinematics

In the characteristic positions and phases, the angles [°] and amplitudes [°] were recorded for the following figurative points: trunk in relation to the horizontal plane (angle), center of the hip joint and center of the knee joint. The center of the ankle and the center of the shoulder joint were used to define the longitudinal axes that define the angles in the joints of research interest. Angles were recorded and compared in the LO and KP positions. Amplitudes were recorded in the LO-KP, KP-LC and LO-LC phases. Also, to calculate the kinetic variable (performed mechanical work), vertical distance traveled [m]

was monitored by tracking the movement of the center of the bar. All variables were processed in Kinovea motion analysis software, version 0.8.15.

Kinetics

The performed mechanical work [Nm] in one lifting was calculated by multiplying the vertical distance traveled [m] by the weight of the bar.

Electromyography

The average amount of muscle activation normalized to the maximal voluntary contraction during the concentric and eccentric phases was monitored, for all 18 individual lifting repetitions (3 series \times 3 repetitions \times 2 techniques), separately for all muscles. The analysis took into account only repetitions that meet the criteria of proper technique and duration of movement, as well as repetitions with "clean" EMG signals. The separation of the concentric and eccentric phases was clearly noticeable by the pause between lifting and lowering of the weight. The maximal voluntary activation and the amount of muscle activation were expressed as the average area of the rectified and smoothed EMG signal using the "root mean square" algorithm for raw EMG signal processing. The window length used was 0.1s and the window overlap was 0.08s. Delsys Trigno telemetry sensors were used to monitor EMG muscle activity. The data were processed in EMGworks software. All used equipment was from the American company Delsys.

Statistical data analysis

The results are presented using descriptive and comparative statistics. Of the descriptive statistical parameters, the mean value and standard deviation was used, and of the comparative analysis of variance with repeated measurements (ANOVA).

To determine the influence of two factors – the weight position and the applied technique – on the kinematic variables (angles and amplitudes), the results were analyzed by two-way analysis of variance with repeated measurements (2 positions \times 2 techniques). The differences between the two techniques in vertical weight distance traveled and performed mechanical work were calculated using one-way analysis of variance with repeated measurements. The differences between the two techniques in electromyographic activity were calculated using one-way analysis of the variance with repeated measurements. If the analysis of variance showed a significant influence on the interaction of two factors on one of the monitored variables, the analysis of simple influences was done, within which the influence of technique change was analyzed, for each weight position (both LO and KP).

Statistical data processing was performed in the SPSS data processing program, version no. 17. The P-value for determining statistically significant differences was set to <0.05 .

RESULTS

Kinematics

Tables 2 and 3 show the basic descriptive statistical parameters for the trunk angle in relation to the horizontal plane, the angle in the hip joint and the angle in the knee joint in the LO and KP position.

Table 2. Basic descriptive statistical parameters for the trunk angle in relation to the horizontal plane, angle in the hip and knee joint in the LO position, for DL_{con} and DL_{su} technique.

	Trunk angle in relation to the horizontal plane [°]	Hip joint angle [°]	Knee joint angle [°]
LO _{con}	23.6±3.5	52.1±3.4	106.5±7.5
LO _{su}	40.5±4.8*	56.8±3.6*	98.7±11.2#

Note: The P-value was set to <0.05. * - statistically significant difference in comparison to DL_{con}; # - tendency towards statistically significant difference.

Table 3. Basic descriptive statistical parameters for the trunk angle in relation to the horizontal plane, angle in the hip and knee joint in the KP position, for DL_{con} and DL_{su} technique.

	Trunk angle in relation to the horizontal [°]	Hip joint angle [°]	Knee joint angle [°]
KP _{con}	41.0±3.0	94.0±5.8	142.2±6.0
KP _{su}	50.6±3.2*	100.0±5.0*	141.8±7.2

Note: The P-value was set to <0.05. * - statistically significant difference in comparison to DL_{con}; # - tendency towards statistically significant difference.

The results show that the difference in the trunk angle in relation to the horizontal plane between techniques is statistically significant, both in the LO and KP position (p<0.05). In both positions, the DL_{su} trunk makes a larger angle with the horizontal plane. Also, a statistically significant difference in the hip joint angle was observed between the techniques in the LO and KP position (p<0.05). In the LO position, the angle at the hip joint was larger when lifting the weight using DL_{su} technique. The angle in the knee joint showed a trend towards statistically significant difference between techniques in LO (p=0.0996), but not in the KP position. In the LO position, the angle at the knee joint was higher when lifting with DL_{con}.

Table 4. Results of two-way analysis of variance with repeated measurements for the trunk angle in relation to the horizontal plane, angle at the hip and knee joint between DL_{con} and DL_{su} technique in LO and KP position.

	Position (LO/KP)	Technique (DL _{con} /DL _{su})	Interaction
Trunk angle in relation to the horizontal	P<0.01	P<0.01	P<0.01
	F=321.99	F=258.71	F=54.09
	Df=1	Df=1	Df=1
	PES=0.98	PES=0.97	PES=0.87
Hip angle	P<0.01	P<0.01	P=0.289
	F=1180.45	F=82.54	F=54.09
	Df=1	Df=1	Df=1
	PES=0.99	PES=0.97	PES=0.14
Knee angle	P<0.01	P=0.01	P<0.01
	F=537.86	F=10.79	F=24.75
	Df=1	Df=1	Df=1
	PES=0.98	PES=0.57	PES=0.76

Note: The following statistical parameters for the effect of position, techniques and their mutual interactions are presented: P-value, F-value, Df – degrees of freedom and Partial eta square (PES) – influence of the variable; Any P-value less than 0.05 was taken as statistically significant.

From Table 4 it can be seen that the angle of the trunk in relation to the horizontal plane was significantly affected by the position of the weight and the performed technique. In other words, their interaction is statistically significant ($p < 0.01$). Post-hoc analysis with Greenhouse-Geisser corrected T-test found a statistically significant difference in the position of the trunk in relation to the horizontal plane between DL_{su} and DL_{con} technique in the LO position ($p < 0.01$, $Df=8$, $t=15.5$), between LO and KP positions for DL_{su} technique ($p < 0.01$, $Df=8$, $t=-8.37$) and for DL_{con} technique ($p < 0.01$, $Df=8$, $t=-40.07$). Statistically significant difference was also found between DL_{su} and DL_{con} technique in the KP position ($p < 0.01$, $Df=8$, $t=11.98$).

The hip joint angle did not show statistically significant interaction between the influence of the weight position and the deadlift technique ($p=0.29$), because trend in its change was similar. Two different techniques affect the change of the variable equally, both in LO and KP positions. In addition, there was statistically significant difference both in the position of the weight ($p < 0.01$, $Df=1$) and between performance techniques ($p < 0.01$, $Df=1$).

The angle at the knee joint also showed statistically significant interaction of the weight position and the deadlift technique ($p < 0.01$). The difference in technique at LO position was statistically significant ($p < 0.01$, $t=4.05$, $Df=8$). Different techniques in KP position, on the other hand, do not differ significantly ($p=0.65$, $t=0.52$, $Df=8$). The transition from LO to KP position showed statistically significant differences in the knee joint angle and DL_{su} ($p < 0.01$, $t=-20.01$, $Df=8$) and DL_{con} techniques ($p < 0.01$, $t=-32.09$, $Df=8$).

Tables 5 and 6 show the total amplitudes during lifting phases in the hip joint, i.e. in the knee joint.

Table 5. Amplitudes in the hip joint in LO-KP phase, KP-LC phase and total amplitude from LO to LC [°].

Hip	LO-KP [°]	KP-LC [°]	LO-LC [°]
DL_{con}	41.9±4.9	86.0±5.8	127.9±3.4
DL_{su}	43.3±3.4	80.0±5.0*	123.2±3.6*

Note: The P-value was set to < 0.05 . * - statistically significant difference in comparison to DL_{con} ; # - tendency towards statistically significant difference.

Table 6. Amplitudes in the knee joint in LO-KP phase, KP-LC phase and total amplitude from LO to LC position [°].

Knee	LO-KP [°]	KP-LC [°]	LO-LC [°]
DL_{con}	36.1±4.9	37.4±5.4	73.5±7.5
DL_{su}	43.2±6.5*	38.2±7.2	81.3±11.2#

Note: The P-value was set to < 0.05 . * - statistically significant difference in comparison to DL_{con} ; # - tendency towards statistically significant difference.

In Table 5, it can be seen that the extension in the hip joint did not differ significantly between techniques in the first (LO-KP) phase, but that it did differ significantly in the second (KP-LC) phase. Also, the total amplitude (LO-LC) differed significantly between techniques. In Table 6 it can be noticed that the knee extended significantly more in the first (LO-KP) phase when lifting the weight using DL_{su} technique compared to DL_{con} technique. In the second (KP-LC) phase, there was no significant difference between the two techniques, but the total amplitude (LO-LC) showed a trend towards statistically significant difference ($p=0.0996$).

Kinetics

Table 7 showed the performed mechanical work for DL_{con} and DL_{su} technique from LO to LC position.

Table 7. Performed mechanical work [Nm- Newton meter] for DL_{su} and DL_{con} technique, as the product of the vertical weight distance traveled [m-meter] and the weight of the bar [N-Newton].

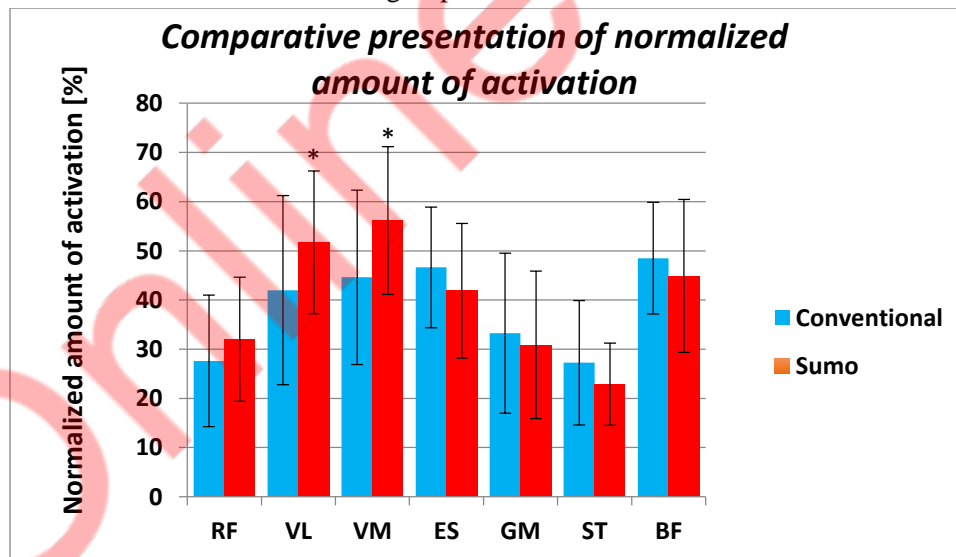
	Vertical distance traveled [m]	Weight [N]	Mechanical work [Nm]
DL _{con}	0.72±0.05	708.5±107.2	512.4±98.2
DL _{su}	0.62±0.05	708.5±107.2	441.5±86.2*

Note: Values are presented through their mean and standard deviation. The P-value was set to <0.05. * - statistically significant difference in comparison to DL_{con}; # - tendency towards statistically significant difference.

One-way analysis of variance with repeated measurements revealed statistically significant difference in the performed mechanical work in favor of DL_{con} technique (p<0.01), since the subjects lifted the same weight with both techniques.

Electromyography

Graph 1 presents a comparative presentation of the normalized amount of muscle activation, as well as standard deviations for all tested muscle groups.



Graph 1. Comparative graphical representation of the normalized amount of muscle activation in relation to the maximal voluntary contraction;

Note: RF – m. rectus femoris, VL – m. vastus lateralis, VM – m. vastus medialis, ES – lumbar part m. erector spinae, GM – m. gluteus maximus, ST – m. semitendinosus, BF – m. biceps femoris caput longum. Data are presented through their mean and standard deviation. The P-value was set to <0.05. * - statistically significant difference in comparison to DL_{con}; # - tendency towards statistically significant difference.

Table 8. Results of one-way analysis of variance with repeated measurements for the amount of muscle activation of different muscles between DL_{con} and DL_{su} technique.

Muscle	<i>m. rectus femoris</i>	<i>m. vastus lateralis*</i>	<i>m. vastus medialis*</i>	<i>m. erector spinae (L3-L4)</i>	<i>m. gluteus maximus</i>	<i>m. semitendinosus</i>	<i>m. biceps femoris (caput longum)</i>
Statistical analysis	P=.22 F=1.84 Df=1 P. Eta Sq=0.21	P=.02 F=9.83 Df=1 P. Eta Sq=0.58	P=.03 F=7.89 Df=1 P. Eta Sq=0.53	P=.18 F=2.19 Df=1 P. Eta Sq=0.24	P=.56 F=0.38 Df=1 P. Eta Sq=0.05	P=.22 F=1.83 Df=1 P. Eta Sq=0.21	P=.49 F=0.52 Df=1 P. Eta Sq=0.07

Note: The following statistical parameters are presented: P-value, F-value, Df – degrees of freedom and Partial eta square – influence of the variable; Any P-value less than 0.05 was taken as statistically significant.

It can be noticed that the *m. quadriceps femoris* (*m. rectus femoris*, *m. vastus medialis* and *m. vastus lateralis*) showed a higher total amount of activation during lifting with the DL_{su} technique. Statistically significant difference was present in *m. vastus lateralis* ($p < 0.05$) and *m. vastus medialis* ($p < 0.05$), while in *m. rectus femoris* was not. The results showed greater activation of the lumbar region *m. erector spinae* with DL_{con} ($46.6 \pm 19.2\%$) compared to DL_{su} ($41.9 \pm 13.7\%$) technique, but with no statistically significant difference. *M. gluteus maximus* was also more active with DL_{con} ($33.3 \pm 16.3\%$) compared to DL_{su} ($30.9 \pm 15\%$) technique, but there was also no statistically significant difference. The results of a one-way analysis of variance with repeated measurements showed that there was no statistically significant difference in the total amount of hamstrings activation. With DL_{con} technique, *m. semitendinosus* showed higher activation ($27.3 \pm 12.7\%$) compared to DL_{su} (22.9 ± 8.3) technique. According to the obtained results, *m. biceps femoris caput longum* was more activated with DL_{con} ($48.5 \pm 11.3\%$) than with DL_{su} ($44.9 \pm 15.5\%$) technique.

DISCUSSION

The aim of this study was to determine the differences between the two variants of deadlift technique – conventional and sumo – from kinematic, kinetic and electromyographic perspective. Nine physically active males were recruited for this study. Subjects lifted the weight that was similar to their body weight. The load was alternately lifted with the two techniques after every serial. A total of 3 deadlifting series were performed with 3 controlled liftings and lowerings within one serial (3 seconds concentric and 3 seconds eccentric phase). Used kinematic variables were the trunk angle in relation to the horizontal plane, the hip joint angle and the knee joint angle in the LO and KP position, then the amplitudes in the mentioned joints during LO-KP, KO-LC and LO-LC phases, as well as the vertical weight distance traveled. Of the kinetic variables, the performed mechanical work was examined. The amount of muscle activation was monitored for *m. erector spinae (L3-L4)*, *m. gluteus maximus*, *m. vastus medialis*, *m. vastus lateralis*, *m. rectus femoris*, *m. biceps femoris caput longum* and *m. semitendinosus*. The theoretical significance of this research is reflected in its contribution and deepening of this issue, given that it was done with a different research methodology. On the other hand, the practical significance of this research is reflected in the possibility of planning and programming sports or recreational training process by choosing the appropriate lifting technique.

In accordance with the previous research (Cholewicki et al., 1991; McGuigan & Wilson, 1996; Escamilla et al., 2000), in this study the results showed that in the LO position the trunk angle relative to the horizontal plane is significantly higher when lifting the loads with DL_{su} technique. Also, the angle at the hip joint is significantly larger, unlike in the previous researches (McGuigan & Wilson, 1996), while

the angle at the knee joint showed tendency to be significantly smaller. In the KP position, significant difference was observed in the trunk angle in relation to the horizontal plane and in the angle at the hip joint, where the trunk tilt with DL_{con} technique was still significantly smaller. All these results suggest that within the same subjects, two initial positions for load lifting have two significantly different forms, but that the differences are practically canceled through the amplitude of movement when it comes to the knee joint, but not to the hip joint. This is supported by the results of this study, according to which there was significant difference in amplitudes in the hip joint from KP to LC position and tendency towards significant difference in the total amplitude from LO to LC position. Practically, the initial differences that exist still remain in the transit position due to slightly small differences in amplitude from LO to KP position. On the other hand, the tendency towards significant difference in the knee joint in the initial position was practically canceled in the transit position through the amplitude. All these differences in amplitudes at the appropriate phases influenced the appearance of significant difference in the total amplitude in the hip joint and the appearance of tendency towards significant difference in the knee joint. In accordance with the previous research (Escamilla et al., 2001) it was obtained a similar result according to which the vertical distance traveled was 16% higher with DL_{con} compared to DL_{su} technique, which can be assumed by the analysis of the initial position – wider posture, narrowly placed arms, lowered center of gravity when lifting with DL_{su} technique, and thus the maximal height to which the weight was lifted. Therefore, since subjects lifted the same weight with both techniques, the performed mechanical work was also significantly higher when lifting the load with DL_{con} technique. The result was obtained in which the mechanical work performed was 25-30% higher when lifting the load using DL_{con} in relation to DL_{su} technique (Escamilla et al., 2001). On the other hand, it is generally known that in most cases, more weight can be overcome by lifting with DL_{su} technique. Perhaps using different weights of the bar would lead to similar results.

When it comes to electromyographic differences between lifting techniques, the only significant difference was observed between the medial and lateral head of *m. quadriceps femoris*, in accordance with the previous researches (Escamilla et al., 2001). On the other hand, it is clear from Graph 1 that the postural muscle chain (*m. erector spinae*, *m. gluteus maximus*, *m. semitendinosus* and *m. biceps femoris caput longum*) was more pronounced with DL_{con} technique, but that the difference was not significant. Namely, the difference of 4.7 degrees in the hip joint in the LO position, and thus the initial length of the diagonally placed *m. gluteus maximus* may not be sufficient to manifest a difference in its activation. The results support the fact that the initial position and external load moment arms actually determine the electromyographic differences between techniques, so that a greater inclination of the trunk or a smaller angle in the knee joint causes greater manifestation of agonistic and synergistic extensors in the given joints.

The results of this research also have certain practical implications within training periodisation. For example, the application of any technique for beginners will certainly have a large training effect, but the general recommendation would be the use of DL_{con} technique at the beginning of the training process due to necessity for greater development of postural muscle groups, and thus the stability of the trunk in later stages of the training process. On the other hand, in rehabilitation practice, the presence of injury or damage to individual joints (for example, knee joint) should direct the training process towards the application of DL_{con} technique, because the amplitude in the knee joint was slightly smaller and the load is overcome from a slightly more favorable position (for example, the reverse would be applied if an injury to the lower back is present, so it would be recommended to apply DL_{su} technique).

In order to look at this issue even more objectively and in the most methodologically correct way, in some future research it would be important to apply load relativization in relation to 1 repetitive maximum (1 RM), instead of the weight that is close to the weight of the individual subjects. Also, it would be important to repeat the research on a larger number of subjects, knowing that people have different body compositions within the same body mass and that in most cases more weight can be overcome by DL_{su} technique. Perhaps this methodological approach would provide more significant differences between, for example, levels of neuromuscular activation of postural muscles.

CONCLUSION

The results of this study showed that significant differences were obtained in the initial angular positions in all monitored joints, as well as in the transition position when it comes to the trunk angle in relation to the horizontal plane and the angle in the hip joint. The trunk angle in relation to the horizontal plane and the angle in the hip joint were larger with DL_{su} technique, while the angle in the knee joint was larger with DL_{con} technique. Also, significant differences were obtained between techniques in amplitudes in the hip joint in the KP-LC phase and in total amplitude, as well as in the knee joint in the LO-KP phase and in total amplitude. Amplitudes in the hip joint were larger with DL_{con} technique, while amplitudes in the knee joint were larger with DL_{su} technique. The performed mechanical work was significantly larger when lifting with the DL_{con} technique. Activation of medial and lateral heads of *m. quadriceps femoris* was significantly larger when lifting with DL_{su} technique, and activation of postural muscle groups (*m. erector spinae*, *m. gluteus maximum*, *m. semitendinosus* and *m. biceps femoris caput longum*) was larger when lifting with DL_{con} technique, but not statistically significant. It was suggested to repeat the research on a larger number of subjects and to apply the technique relativization in relation to 1 repetitive maximum (1 RM).

REFERENCES

1. Andersen V, Fimland MS, Mo DA, Iversen VM, Vederhus T, Hellebø LRR (2018). *Electromyographic comparison of barbell deadlift, hex bar deadlift, and hip thrust exercises: a cross-over study*. J Strength Cond Res.
2. Barbero, M., Merletti, R., & Rainoldi, A. (2012). *Atlas of muscle innervation zones: understanding surface electromyography and its applications*. Springer Science & Business Media.
3. Bezerra ES, Simão R, Fleck SJ, Paz G, Maia M, Costa PB, (2013). *Electromyographic activity of lower body muscles during the deadlift and stiff-legged deadlift*.
4. Camara, K. D., Coburn, J. W., Dunnick, D. D., Brown, L. E., Galpin, A. J., & Costa, P. B. (2016). *An examination of muscle activation and power characteristics while performing the deadlift exercise with straight and hexagonal barbells*. The Journal of Strength & Conditioning Research, 30(5), 1183-1188.
5. Cholewicki, J., McGill, S. M., & Norman, R. W. (1991). Lumbar spine loads during the lifting of extremely heavy weights. *Medicine and science in sports and exercise*, 23(10), 1179-1186.
6. Criswell, E. (2010). *Cram's introduction to surface electromyography*. Jones & Bartlett Publishers.
7. ESCAMILLA, R., FRANCISCO, A., FLEISIG, G., BARRENTINE, S., WELCH, C., KAYES, A., ... & ANDREWS, J. (2000). A three-dimensional biomechanical analysis of sumo and conventional style deadlifts. *Medicine & Science in Sports & Exercise*, 32(7), 1265-1275.
8. Escamilla, R. A. F. A. E. L., Lowry, T. R. A. C. Y., Osbahr, D. A. R. Y. L., & Speer, K. E. V. I. N. (2001). Biomechanical analysis of the deadlift during the 1999 Special Olympics World Games. In *ISBS-Conference Proceedings Archive*.
9. Escamilla, R. F., Francisco, A. C., Kayes, A. V., Speer, K. P., & Moorman 3rd, C. T. (2002). An electromyographic analysis of sumo and conventional style deadlifts. *Medicine and science in sports and exercise*, 34(4), 682-688.

10. Hamlyn N, Behm DG, Young WB (2007). *Trunk muscle activation during dynamic weight-training exercises and isometric instability activities*. J Strength Cond Res.
11. Kasovic J, Martin B, Fahs CA (2019). *Kinematic Differences Between the Front and Back Squat and Conventional and Sumo Deadlift*. J Strength Cond Res.
12. Korak JA, Paquette MR, Fuller DK, Caputo JL, Coons JM (2018) *Muscle activation patterns of lower-body musculature among 3 traditional lower-body exercises in trained women*. J Strength Cond Res.
13. Krings BM, Shepherd BD, Swain JC, Turner AJ, Chander H, Waldman HS,(2019). *Impact of fat grip attachments on muscular strength and neuromuscular activation during resistance exercise*. J Strength Cond Res.
14. Lake, J., Duncan, F., Jackson, M., & Naworynsky, D. (2017). *Effect of a hexagonal barbell on the mechanical demand of deadlift performance*. Sports, 5(4), 82.
15. Lee S, Schultz J, Timgren J, Staelgraeve K, Miller M, Liu Y (2018). *An electromyographic and kinetic comparison of conventional and Romanian deadlifts*. J Exerc Sci Fit.
16. Mannie, K. (1997). ORGANIZING THE OFF-SEASON STRENGTH-TRAINING PROGRAM. *Scholastic Coach & Athletic Director*, 66(9), 24-27.
17. McGuigan, M. R., & Wilson, B. D. (1996). Biomechanical analysis of the deadlift. *The Journal of Strength & Conditioning Research*, 10(4), 250-255.
18. Nijem RM, Coburn JW, Brown LE, Lynn SK, Ciccone AB (2019). *Electromyographic and force plate analysis of the deadlift performed with and without chains*. J Strength Cond Res.
19. Piper, T. J., & Waller, M. A. (2001). Variations of the deadlift. *Strength & Conditioning Journal*, 23(3), 66.
20. Swinton, P. A., Stewart, A., Agouris, I., Keogh, J. W., & Lloyd, R. (2011). *A biomechanical analysis of straight and hexagonal barbell deadlifts using submaximal loads*. The Journal of Strength & Conditioning Research, 25(7), 2000-2009.