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Comparison of EMG Activity between Single-Leg Deadlift and Conventional Bilateral Deadlift in Trained Amateur Athletes - An Empirical Analysis

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ABSTRACT

International Journal of Exercise Science 14(1): 187-201, 2021. The purpose of the study was to compare the normalized-electromyographic (NEMG) activity of the gluteus maximus (GMAX), gluteus medius (GMED), biceps femoris (BF) and erector spinae (ES) muscles during the single-leg deadlift (SLDL) and the conventional-deadlift (DL). Additionally, a potential influence of body height on the NEMG activity was examined. Fifteen training-experienced male subjects completed the study. SLDL showed significantly higher average concentric NEMG values of the GMED (77.6% vs. 59.3% [$p = 0.002$, ES = 1.0]) and BF (82.1% vs. 74.2% [$p = 0.041$, ES = 0.6]). Significantly lower NEMG levels were found only in the left strand of the ES muscle (67.2% vs. 82.7% [$p = 0.004$, ES = 0.9]). A significant influence of body height on EMG activity was also observed for all muscles, with the exception of the GMED, during the SLDL. Body height correlated negatively with the concentric EMG activity of the ES ($r = -0.54$ to -0.58), the BF ($r = -0.63$) and the GMAX ($r = -0.85$). In the DL there was a negative correlation only in the BF ($r = -0.59$) and the GMAX ($r = -0.7$). This means that subjects with a lower body height showed a higher NEMG activity in corresponding muscles. The results of this study indicate that the SLDL is preferable to the DL in training the BF, and GMED. In addition, coaches should be aware that athletes body height can influence the extent to which the respective muscles are activated.

KEY WORDS: hip extensors, knee flexors, bilateral resistance, unilateral resistance, muscle activity

INTRODUCTION

The growing popularity of functional training led coaches to call for an increased use of unilateral leg exercises in order to comply with the training principle of specificity (5, 19). Recent research demonstrates that unilateral leg exercises can achieve comparable or better training effects than similar bilateral exercises (24, 28, 35, 41). Apart from greater specificity and force carryover in the respective target sport form, four primary arguments for the use of unilateral exercises are given (8, 14, 16, 29): (i) lower risk of injury to the torso due to reduced axial load on the spine in comparison to bilateral exercises; (ii) higher activation of joint-stabilizing musculature, which can contribute to increased loading in the three planes of movement and help to control excessive evasive movements; (iii) correction of any asymmetries between limbs and the underlying muscular imbalances an athlete might possess, as it has been shown that bilateral asymmetries of >15% increase the risk of injuries (20) and reduce sports performance (25); (iv) higher potential force production per limb during unilateral training compared to similar bilateral exercises due to bilateral deficit (BLD).

Furthermore, in previous investigations, the BLD was consistently observed in force during simultaneous knee and hip extensions, but not in electromyography (EMG) (23, 37, 38). So far, only a few studies have compared surface EMG activity during free unilateral and bilateral leg exercises (3, 11, 18, 26, 27). In two of these studies, the methodological procedure also hinders correct assessment of the BLD in EMG, because the testing intensity of the unilateral variant was determined at 50 % of the bilateral variant (3, 11). Since BLD is strongly influenced by unilateral training and previous training history (14, 37), a 50% intensity reduction without testing for the corresponding load does not lead to an adequate activation comparison because the intensity of both exercises did not match. Therefore, only a few studies compared unilateral and bilateral exercises in heavy resistance training exercises of equal intensity.

To date, no study has compared the surface EMG activity of the most significant muscles during the single-leg-deadlift (SLDL) to those during the bilateral-deadlift (DL) using the same percentage of the repetition maximum. Previous exercise comparisons by McCurdy et al. (26, 27) and Deforest et al. (11) and ongoing observation of the BLD during simultaneous knee and hip extensions (23, 37, 38) suggest that the EMG activity of the gluteus medius (GMED), gluteus maximus (GMAX), and biceps femoris (BF) is higher during the SLDL than during the DL. In contrast, a lower EMG activity of the erector spinae (ES) can be expected due to the lower absolute loads for the SLDL.

EMG activity is related to the respective muscle length and the associated joint angles (10, 31). A relationship between anthropometric parameters and EMG activity could be assumed, since it has been shown that anthropometric parameters, such as body height, also have an influence on the performance parameters of the DL (22). However, it has not been investigated whether anthropometric parameters have an influence on EMG activity during lower body lifting exercises. This knowledge is essential for coaches to be able to create programs suitable to the demands of different sports and to the individual athlete’s needs.

Therefore, the primary purpose of this study is to compare the EMG activity of the GMED, GMAX, BF, and ES between SLDL and DL at the same relative intensity. Furthermore, the secondary purpose is to investigate whether there is a relationship between EMG values and body height. The hypotheses to be reviewed are: (H1) during unilateral SLDL, in comparison to bilateral DL, significantly higher EMG activity of the muscles GMAX, GMED, and BF can be measured, while lower activities of the left and right ES can be observed; (H2) there is a correlation between body height and EMG values for SLDL and DL.

METHODS

Participants

A power analysis was performed with G*Power (Version 3.1.9.2, Universität Kiel, Germany). It was calculated that a sample size of 16 subjects is sufficient to achieve a statistical power of 95%. All subjects were male ($N = 16$) with a mean age, body mass, and height of 31.3 years (SD = 8.9), 80.4 kg (SD = 11.1), and 180 cm (SD = 6.5 cm). All volunteers signed a consent form explaining the background and risks of the study. At the time of the study, no participants suffered from pain, illness or injury. To ensure acute habituation to the two exercises, all subjects underwent a two-month habituation phase in which both exercises were performed at least once a week. For this purpose, subjects were instructed at least once in the correct execution in preliminary meetings. In the preceding training, 12-15 repetitions and six to eight repetitions were alternated evenly, with sessions of six to eight repetitions used regularly to determine the current maximum load at eight repetitions (8RM). Participants were asked to refrain from lower body strength training for 48 hours before testing to exclude possible fatigue effects. The local ethics commission confirmed that the requirements of the Declaration of Helsinki were met. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (30).

Protocol

A Within-Subject design was used to compare the neuromuscular activity of the GMAX, GMED, BF and ES during the SLDL and DL with the respective 8RM (27, 36). The right leg was examined electromyographically during both exercises. The individual 8RM load was determined in the last training session, which took place at least 48 hours before the measurement. To ensure identical electrode placement, the EMG data of both exercises were recorded in the same run. The order in which these exercises were performed was randomized between subjects to ensure nonbiasing of data (21).

EMG amplitude measured during exercise execution was recorded for the GMAX, GMED, and BF of the right leg, and left and right strand of the ES. Since these muscles are primarily responsible for execution of the tested movements and allow comparison with other studies in which the EMG amplitude was investigated in one-leg exercises (3, 11, 12, 26, 27) and DL (1, 13), they were specifically selected. Preparation of the skin and the placement of the electrodes were carried out according to the specifications of the *SENIAM Project* (15). The first four electrodes were attached in the prone position; for the GMAX, halfway between the os sacrum and the greater trochanter; for the BF, halfway between the tuber ischiadicum and the lateral condyle tibiae; for the left and right strand of the ES, two finger widths each from the spinosus L1 process. The fifth electrode for the GMED was placed in the lateral position, halfway between the greater trochanter and the iliac crest. The corresponding sites were first marked, shaved, and cleaned with 70% isopropanol. Electrodes were then placed on the middle of the muscle belly, parallel to the orientation of the muscle fibers. For stronger fixation, electrodes were additionally covered with *Fixomull® Stretch* patches.

For testing, a standard 20kg Olympic weightlifting barbell, as well as solid rubber bumper plates with a disc diameter of 450mm according to the IWF standard, was used. Prior to the testing, the subjects completed a warm-up program consisting of a 5-minute dynamic stretching followed by 2x8 repetitions at increasing loads of 30% and 50% of their 8RM with a 1-minute break in between (26, 27). For the SLDL, warm-ups were executed successively with the left and right leg, although measurement was taken from the right side only. Pauses of 5 minutes were assigned between measurements to avoid fatigue (6, 13). Five repetitions per exercise were recorded electromyographically (18). Through the use of acoustic timer signals (Gymboss® Interval-Timer), the controlled execution of the concentric/eccentric movement phase and pause between repetitions was normalized to four seconds per repetition (13, 21). This procedure was deliberately chosen to ensure a higher comparability of the integrated EMG signals, as the IEMG shows a more reliable relationship to produced force (32). A pause of approximately two seconds was inserted between the repetitions to separate the EMG data of the individual repetitions (13). The measurements were performed barefoot to exclude any potential influences of different footwear (2, 34). Furthermore, no supporting equipment was used (e.g. weightlifting belts, pulling-aids). The foot position during DL was self-selected. Because the motion sequence of the SLDL has not been described in detail in any known publication so far, it is described in more detail below. Participants began in an upright, offset position, with the support leg positioned centrally in front of the barbell. From here on the starting position was adopted (Figure 1, A).

The standing leg side was bent at the knee and hip, while the back was kept extended. The knee of the standing leg was bent only as far as it was needed to maintain a straight back. A posture with the upper body parallel to the ground is optimal, as a larger flexion angle of the knee impairs the close, upward movement of the barbell. The unloaded straight leg was extended behind the body to counterbalance the forward bending of the upper body. The barbell was gripped with both hands (pronated) at shoulder width and the back was brought into a pretension by activating the latissimus dorsi muscle, the abdominal muscles, and by retracting the shoulder blades. In the concentric phase, the upper body was straightened until the standing leg hip was completely extended (Figure 1, B). The barbell was pulled upwards as close as possible to the knee in order to keep the load arm shortest at the hip rotation axis. The straight rear leg was moved along with the extended hip and in extension of the back so that, in the upright end position, it was almost at the level of the standing leg; the front foot was allowed to be set down on the floor briefly for stabilization. To complete the repetition, the buttocks and the abdomen were tensed so that the lumbar spine was in a neutral position. Following a brief isometric holding time in the upper end position, eccentric downward movement was initiated back to the starting position and the weight was lowered to the ground in a controlled manner as close to the body as possible.

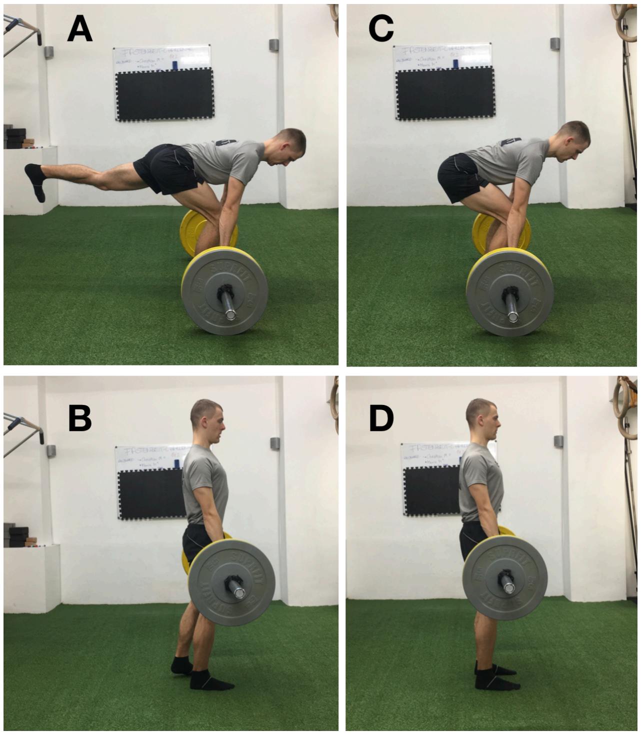

Figure 1. Start- and end positions of SLDL (A, B) and DL (C, D)

Following both measurements, the maximal-voluntary-isometric-contraction (MVIC) test was performed after a 5-minute rest period to normalize the recorded EMG data. The MVIC tests were carried out after testing, as in the previous EMG DL studies (1, 12, 13), because participants were warmed up but not fatigued. For each muscle, two MVIC tests with one-minute rest intervals were performed in randomized order to minimize errors due to accumulated fatigue (21). Test subjects were instructed to build up maximal tension over three seconds and maintain it for five seconds. Subjects were verbally encouraged by the researchers to increase motivation. Measurement recording was paused during exercise and position changes. The GMAX, BF, and strands of the ES on both sides were tested manually by the examiner with participants in prone position. The MVIC of the GMAX was performed with knee angled at 90°, with participants extending the hip against resistance at the distal end of the thigh (9). For the BF, the pelvis was secured with a knee flexion of approx. 30°. From this position, participants bent the knee against resistance at ankle level (1). The testing of the ES started from a slight hyperextension. The test subjects should tighten with maximum force against the fixation on the shoulder girdle. GMED was tested in a lateral position with approx. 25-30° abduction in the hip joint against the resistance of the examiner at the knee and foot (4).

Raw EMG signal was recorded using a wireless SEMG (*Delsys® Trigno™*, Boston, MA). The system signal bandwidth was 20-450Hz with a range of 20Hz. The transmission frequency was 2.4GHz and the Common-Mode-Rejection-Ratio (CMRR) was > 80dB. *EMGworks® Acquisition* (*Delsys*, Natick, MA, USA) was used to record the EMG raw data. The EMG data was imported into the analysis software *EMGWorks Analysis* for further processing. Raw EMG baseline was checked for a possible shift within the program using the Remove-Mean-Calculation. The mean concentric, eccentric, and combined EMG values were then calculated using the RMS calculation for the three middle repetitions with a sliding window length of 50ms. The mean EMG amplitudes for each repetition were calculated for concentric, eccentric, and combined movement phases. Mean values for each muscle and contraction type were calculated in Excel (*Microsoft*, Redmond, WA, USA) from the amplitude values of the three middle repetitions. An RMS with a window length of 500ms was calculated for each MVIC test. The highest of the two mean amplitude values was used as the reference value for MVIC normalization.

Statistical Analysis

The dependent variables were the normalized EMG values for the SLDL and DL exercises. The independent variables were contraction type (eccentric, concentric, or combined) and the respective muscle being studied (GMAX, GMED, BF, left/right ES). Both independent variables were Within-Subject (repeated measurement) variables. The statistical calculations to check for significant differences between dependent variables were performed in Excel. The Statistics Package for Social Sciences (Version 25.0; IBM Corporation, New York, USA) was used for testing for normal distribution and to calculate the bivariate correlation coefficients. Testing for normal distribution was performed with the Kolmogorov-Smirnov and the Shapiro-Wilk test. Subsequently, the two-sample t-Test for dependent samples measured differences between the normalized EMG measurement pairs. All tests were carried out at the two-sided significance ($p < 0.05$ and $p < 0.01$). Cohen's d effect size was calculated to determine the size and relevance of the statistical difference.

The correlation coefficient according to Bravais-Pearson examined the relationship between body height and normalized EMG values.

RESULTS

Out of initially 16 subjects, 15 completed the study; one subject discontinued the experiment due to muscular hardening and subsequent pain. Means of the individual 8RM loads for DL and SLDL were 112.8kg (SD = 24.2) and 62.7kg (SD = 16.0) respectively.

The EMG data for the MVIC normalized RMS values for the concentric, eccentric, and combined movement phases are reported in Tables 1–3. In the concentric phase, with the exception of the GMAX ($p = 0.25$; ES = 0.3) and right strand of the ES ($p = 0.061$; ES = −0.5), the EMG activities for DL and SLDL differ significantly.

Table 1. Concentric mean EMG activity (mean values ± SD [%] of MVIC)

Muscle	Unilateral	Bilateral	Delta	p	ES
GMED	77.6 ± 20.3	59.3 ± 22.7	18.3	$p = 0.002$	1.0
ES RIGHT	66.2 ± 22.3	75.5 ± 17.4	–9.3	$p = 0.061$	–0.5
ES LEFT	67.4 ± 20.0	82.7 ± 26.8	–15.3	$p = 0.004$	–0.9
BF	82.1 ± 30.9	74.2 ± 28.8	7.9	$p = 0.041$	0.6
GMAX	91.7 ± 28.2	85.7 ± 29.2	6.0	$p = 0.25$	0.3

Table 2. Eccentric mean EMG activity (mean values ± SD [%] of MVIC)

Muscle	Unilateral	Bilateral	Delta	*p*	ES
GMED	55.3 ± 15.5	29.5 ± 14.9	25.9	$p < 0.001$	2.3
ES RIGHT	45.7 ± 13.0	62.4 ± 13.8	–16.7	$p < 0.001$	–1.1
ES LEFT	47.3 ± 15.1	65.6 ± 19.8	–18.3	$p < 0.001$	–1.1
BF	50.0 ± 15.9	37.3 ± 18.1	12.7	$p < 0.001$	1.2
GMAX	46.9 ± 10.9	28.7 ± 9.8	18.2	$p < 0.001$	1.7

Table 3. Combined mean EMG activity (mean values ± SD [%] of MVIC)

Muscle	Unilateral	Bilateral	Delta	*p*	ES
GMED	68.1 ± 17.2	47.8 ± 19.3	20.3	$p < 0.001$	1.4
ES RIGHT	56.8 ± 17.3	69.8 ± 15.3	–13.0	$p = 0.009$	–0.8
ES LEFT	58.7 ± 16.5	76.1 ± 23.2	–17.4	$p = 0.001$	–1.1
BF	68.9 ± 24.8	60.2 ± 25.2	8.7	$p = 0.014$	0.7
GMAX	73.4 ± 19.5	65.6 ± 20.0	7.8	$p = 0.045$	0.6

Integrated EMG values of the concentric phase differed significantly for all investigated muscles and are listed in Table 4.

Table 4. Concentric mean IEMG activity (mean ± SD)

Muscle	Unilateral	Bilateral	Delta (%)	*p*	ES
GMED	365 ± 111	209 ± 74	42.8	$p < 0.001$	1.6
ES RIGHT	446 ± 148	554 ± 207	–24.2	$p = 0.011$	–0.8
ES LEFT	428 ± 134	529 ± 183	–23.7	$p = 0.011$	–0.8
BF	542 ± 178	428 ± 135	21.1	$p = 0.002$	1.0
GMAX	309 ± 146	260 ± 147	15.9	$p = 0.001$	1.0

The correlations of body height, and NEMG values for the SLDL are shown in Tables 5–7 and for the DL in Tables 8–10. With the exception of the GMED, the SLDL showed a significant influence of body height on the concentric NEMG values. Body height correlated negatively with the concentric NEMG activity of the ES ($r = -0.54$ to –0.58), the BF ($r = -0.63$) and the GMAX ($r = -0.85$), meaning that subjects with a lower body height displayed higher NEMG activity. With DL, there was a negative association between body height and concentric NEMG values only for BF ($r = -0.59$) and GMAX ($r = -0.7$).

Table 5. Pearson correlations SLDL (concentric)

		Body Height	Contraction	GMED	ES right	ES left	BF	GMAX
Body Height	*r*	1	.142	.102	–.579*	–.537*	–.630*	–.851**
	p		.613	.718	.024	.039	.012	.000
Contraction Time	*r*	.142	1	.033	–.490	–.407	–.033	–.404
	p	.613		.907	.064	.133	.906	.135
GMED	*r*	.102	.033	1	–.229	–.346	–.158	.132
	p	.718	.907		.412	.207	.574	.638
ES right	*r*	–.579*	–.490	–.229	1	.734**	.602*	.754**
	p	.024	.064	.412		.002	.018	.001
ES left	*r*	–.537*	–.407	–.346	.734**	1	.704**	.687**
	p	.039	.133	.207	.002		.003	.005
BF	*r*	–.630*	–.033	–.158	.602*	.704**	1	.648**
	p	.012	.906	.574	.018	.003		.009
GMAX	*r*	–.851**	–.404	.132	.754**	.687**	.648**	1
	p	.000	.135	.638	.001	.005	.009	

*. Level of significance: 0.05 (2-tailed)

**. Level of significance: 0.01 (2-tailed)

Table 6. Pearson correlations SLDL (eccentric)

		Body Height	Contraction	GMED	ES right	ES left	BF	GMAX
Body Height	*r*	1	–.074	.120	–.582*	–.199	–.490	–.469
	p		.793	.670	.023	.478	.064	.078
Contraction Time	*r*	–.074	1	.202	–.196	.211	–.126	.244
	p	.793		.470	.483	.451	.655	.380
GMED	*r*	.120	.202	1	.093	–.247	–.033	.674**
	p	.670	.470		.741	.374	.906	.006
ES right	*r*	–.582*	–.196	.093	1	.469	.374	.432
	p	.023	.483	.741		.078	.169	.108
ES left	*r*	–.199	.211	–.247	.469	1	.252	.054
	p	.478	.451	.374	.078		.366	.847
BF	*r*	–.490	–.126	–.033	.374	.252	1	.343
	p	.064	.655	.906	.169	.366		.211
GMAX	*r*	–.469	.244	.674**	.432	.054	.343	1
	p	.078	.380	.006	.108	.847	.211	

*. Level of significance: 0.05 (2-tailed)

**. Level of significance: 0.01 (2-tailed)

Table 7. Pearson correlations SLDL (combined)

		Body Height	Contraction	GMED	ES right	ES left	BF	GMAX
Body Height	*r*	1	.043	.113	–.616*	–.443	–.619*	–.852**
	p		.878	.690	.015	.098	.014	.000
Contraction Time	*r*	.043	1	.303	–.304	–.149	–.248	–.041
	p	.878		.273	.270	.597	.373	.883
GMED	*r*	.113	.303	1	–.175	–.342	–.101	.201
	p	.690	.273		.533	.213	.720	.473
ES right	*r*	–.616*	–.304	–.175	1	.657**	.592*	.737**
	p	.015	.270	.533		.008	.020	.002
ES left	*r*	–.443	–.149	–.342	.657**	1	.631*	.540*
	p	.098	.597	.213	.008		.012	.038
BF	*r*	–.619*	–.248	–.101	.592*	.631*	1	.674**
	p	.014	.373	.720	.020	.012		.006
GMAX	*r*	–.852**	–.041	.201	.737**	.540*	.674**	1
	p	.000	.883	.473	.002	.038	.006	

*. Level of significance: 0.05 (2-tailed)

**. Level of significance: 0.01 (2-tailed)

Table 8. Pearson correlations DL (concentric)

		Body Height	Contraction	GMED	ES right	ES left	BF	GMAX
Body Height	*r*	1	–.114	.146	–.426	–.209	–.587*	–.698**
	p		.685	.603	.113	.455	.021	.004
Contraction Time	*r*	–.114	1	–.077	.210	.278	.417	–.150
	p	.685		.786	.453	.316	.122	.595
GMED	*r*	.146	–.077	1	–.135	–.035	–.001	.116
	p	.603	.786		.632	.902	.996	.680
ES right	*r*	–.426	.210	–.135	1	.828**	.651**	.229
	p	.113	.453	.632		.000	.009	.411
ES left	*r*	–.209	.278	–.035	.828**	1	.578*	.044
	p	.455	.316	.902	.000		.024	.878
BF	*r*	–.587*	.417	–.001	.651**	.578*	1	.423
	p	.021	.122	.996	.009	.024		.117
GMAX	*r*	–.698**	–.150	.116	.229	.044	.423	1
	p	.004	.595	.680	.411	.878	.117	

*. Level of significance: 0.05 (2-tailed)

**. Level of significance: 0.01 (2-tailed)

Table 9. Pearson correlations DL (eccentric)

		Body Height	Contraction Time	GMED	ES right	ES left	BF	GMAX
Body Height	*r*	1	–.058	.103	–.458	–.145	–.353	–.712**
	p		.837	.715	.086	.606	.197	.003
Contraction Time	*r*	–.058	1	–.235	–.207	.014	–.376	.527*
	p	.837		.400	.458	.961	.168	.043
GMED	*r*	.103	–.235	1	.155	.282	.337	–.249
	p	.715	.400		.582	.308	.220	.370
ES right	*r*	–.458	–.207	.155	1	.867**	.558*	.249
	p	.086	.458	.582		.000	.031	.371
ES left	*r*	–.145	.014	.282	.867**	1	.396	.220
	p	.606	.961	.308	.000		.144	.431
BF	*r*	–.353	–.376	.337	.558*	.396	1	–.125
	p	.197	.168	.220	.031	.144		.656
GMAX	*r*	–.712**	.527*	–.249	.249	.220	–.125	1
	p	.003	.043	.370	.371	.431	.656	

*. Level of significance: 0.05 (2-tailed)

**. Level of significance: 0.01 (2-tailed)

Table 10. Pearson correlations DL (combined)

		Body Height	Contraction	GMED	ES right	ES left	BF	GMAX
Body Height	*r*	1	–.238	.139	–.460	–.200	–.524*	–.763**
	p		.393	.622	.084	.474	.045	.001
Contraction Time	*r*	–.238	1	–.166	.064	.008	.184	.339
	p	.393		.555	.819	.977	.512	.216
GMED	*r*	.139	–.166	1	–.050	.076	.104	.041
	p	.622	.555		.859	.788	.713	.885
ES right	*r*	–.460	.064	–.050	1	.875**	.712**	.312
	p	.084	.819	.859		.000	.003	.258
ES left	*r*	–.200	.008	.076	.875**	1	.591*	.128
	p	.474	.977	.788	.000		.020	.649
BF	*r*	–.524*	.184	.104	.712**	.591*	1	.425
	p	.045	.512	.713	.003	.020		.114
GMAX	*r*	–.763**	.339	.041	.312	.128	.425	1
	p	.001	.216	.885	.258	.649	.114	

*. Level of significance: 0.05 (2-tailed)

DISCUSSION

The concentric EMG activity of GMED and BF was higher in the SLDL than in the DL. For the GMED, BF, and GMAX, eccentric and combined EMG activity and the concentric IEMG activity during SLDL were higher than for the DL with the exception of the concentric activity of GMAX. Furthermore, with the exception of the concentric EMG activity of the right strand, the EMG activity of ES in all phases and the concentric IEMG activity were significantly higher in DL than in SLDL. Therefore, these findings support H1.

For the SLDL there was a negative correlation between body height and concentric NEMG values of the ES (both sides), BF, and GMAX. The body height also correlated negatively with the combined NEMG values for the right ES, BF, and GMAX. In the eccentric phase, only the NEMG values of the right ES correlated negatively with body height. During the DL, there was a negative correlation between body height and concentric and combined NEMG values of the BF and GMAX and the eccentric NEMG values of the GMAX. Both exercises in the case of the aforementioned muscles were in accordance with H2.

In this study, the presence of a BLD in the EMG during free resistance (16) lower limb exercises could be demonstrated with the example of the SLDL and DL using the same relative intensities (8RM). For SLDL, significantly higher concentric NEMG activity of the GMED and BF could be measured in contrast to the DL (18.3 % and 7.9 %). Also, the mean EMG activity of the GMAX for the SLDL was higher by 6% than for the DL, yet the difference was not significant. These results are consistent with other studies that previously demonstrated BLD in force in machine-guided combined knee and hip extension (23, 37, 38). However, only Magnus and Farthing recorded the EMG activity and could not detect any BLD in the EMG (23).

Since the DL has already been electromyographically investigated in other studies, the EMG values of the present study can be compared with the results of other studies. Camara et al. (6) found comparable NEMG values for the BF (concentric: 83.3%, SD = 9; eccentric 34.7%, SD = 11) and for the ES (concentric: 98.9%, SD = 26; eccentric: 75.3%, SD = 28). Andersen et al. (1) reported slightly higher combined NEMG values for the GMAX (95%, SD = 15), ES (90%, SD = 18) and BF (101%, SD = 21), although the measurements were performed using a 1RM load. In contrast, using a 12RM load, Escamilla et al. (13) identified lower combined NEMG values for the GMAX (35%, SD = 27), ES (32%, SD = 19) and BF (28%, SD = 19),

Considering these results, it is also worth mentioning that it had previously been doubted whether the mechanisms of the BLD could contribute to a higher training stimulus in free unilateral leg exercises than in bilateral leg exercises (16). Since unilateral exercises are generally more unstable than bilateral exercises, Howe et al. (16) speculated that the potential benefits associated with the BLD could be offset by the higher instability of free single-leg exercises. Indeed, some studies have shown that the EMG activity of agonists and force production during strength exercises under unstable conditions is sometimes lower, whereas the EMG activity of stabilizing synergists increases (2). However, the results of this investigation suggest the opposite, as both the activities of the agonists and those of the synergists and the absolute loads per leg were higher in the SLDL than in the DL.

To date, no studies investigated the EMG activity of the GMED during the DL, presumably because the muscle is attributed a predominantly stabilizing function, and a lower need for stabilization can be assumed for bilateral exercises. More surprising are the concentric NEMG values recorded in our study, which amounted to 59.3% (SD = 22.7) and differed from the concentric NEMG values in the SLDL only with an effect strength of 1.0 (77.6%, SD = 20.3).

One of the primary goals of fitness coaches is to increase the strength and performance of their athletes while minimizing the risk of injury during training. In this context, it has been argued that lower back strength is the weakest link in DL, which is why powerlifting at maximum strength often results in a rounded lumbar spine (5, 19, 29). However, under high loads, flexion of the lumbar spine represents a risk of injury to the lower back (7). Based on the use of lower loads, unilateral lower body exercises would have the advantage of avoiding the potential limitation of the lower back (5, 19). Although, ES EMG activity was lower during SLDL (between -9.3% and -18.3%; ES: between -0.5 and -1.1), a larger difference would have been expected in view of the significantly lower loads during the SLDL. One possible cause for the small relative differences in EMG activity of the ES could be due the inclination angles of the trunk. Both exercises differ in the angle of inclination of the torso in the starting position. During the SLDL, the torso was approximately parallel to the ground, while the DL requires a more upright torso position. Participants had to increasingly bend their knee to ensure that the torso remained horizontal. This peculiarity of the SLDL could have contributed to an elongation of the load arm and thus increase the torques at the facet joints of the lumbar spine, which could lead to the observed ES EMG values. Camara et al. (6) also confirm that the torso angle of the DL can influence the EMG activity of the ES. In their investigation EMG activity of the ES was significantly higher in the DL during the eccentric movement phase than in the Hexagon-Barbell DL (75.3%, SD = 28 vs. 61.4%, SD = 21), whereas the difference in the concentric movement phase was 10.9% but not statistically significant (98.9%, SD = 26 vs. 88.0%, SD = 27). Whether significant differences in joint angles contributed to higher EMG values and absolute loads per leg in the SLDL cannot be conclusively assessed, as kinematic parameters were not recorded.

Furthermore, a negative correlation was found for the height and concentric NEMG values of the BF and GMAX for both exercises, as well as for the ES in the SLDL. An explanation for the negative correlation of the BF might be that, due to the shorter distance to the barbell, athletes with a smaller body height were able to perform the movement with less knee flexion. This could have brought the BF closer to its optimal muscle length for maximum force production, which is about 30° knee flexion (40), and is also used for the MVIC test (1). Escamilla et al. (13) examined the NEMG activity as a function of knee joint angle during different DL variants and indicated that the activity rises from approximately 20% at around 85° to over 55% in the joint area between 40 and 30° and is still approximately 50% close to full knee extension. For the GMAX, differences in the hip joint angle may explain the strong negative correlation between body height and concentric NEMG activity. Measurements have shown that the MVIC-EMG activity of the GMAX increases with hip extension (17, 40), which may have resulted in participants of smaller height being able to start from a larger hip angle in both exercises and therefore show higher NEMG values. For both BF and GMAX, the negative correlation was higher in the unilateral condition compared to the bilateral condition (−0.63 vs. −0.59 and −0.85 vs. −0.7), although this difference was small. Somewhat surprising is the high negative correlation between height and concentric NEMG activity of the left and right ES during the SLDL. One may assume that a smaller body height influences the torso angle of inclination in favor of a shorter load arm and, therefore, lower strength requirements, resulting in lower NEMG values. An explanation could be that subjects with a lower body height also had BFs more capable of working closer to the optimal muscle length for maximum power production, which could have increased the performance of the kinetic chain. In such a case, an unfavorable joint angle for the BF would be a limiting factor, which leads to the explanation that the NEMG values of the ES were lower in larger subjects due to the lower realizable loads. It can be assumed that not only the EMG activity, but also the kinematic parameters (39), depends on the load used. The results of this study suggest that in future EMG investigations for DL, body size should also be handled as an influential variable. It can be assumed that the examination of the influence of arm and leg length as well as the arm length to leg length ratio would also reveal relevant correlations with the EMG, as already shown by Lockie et al. (22) for various mechanical parameters. Following the argument that the strength of the back extensors constitutes a limiting performance factor during the DL (5, 19), it also seems promising to study the influence of the torso length on kinematic, electromyographic, and mechanical parameters in DL.

Several limitations of this study require noting. Whether significant differences in the joint angles contributed to the higher EMG values and the absolute loads per leg in the SLDL cannot be conclusively assessed, as no kinematic parameters were recorded. The same restriction also applies to the correlation data presented. In the present study, assumptions about the underlying joint angles were only made on the basis of the observed correlations. It would therefore be instructive to investigate in future studies to what extent individuals adapt their technique to variations of the DL depending on their anthropometric characteristics on the basis of kinematic parameters. Since only men were tested in the present study, it would be necessary to check in the following studies whether these findings are comparable with those of a female subject group. The fact that in this study no connection between body height and absolute bilateral and unilateral 8RM loads could be ascertained could also be attributed to the small sample size and the high-performance heterogeneity. Therefore, this question should be examined in a more homogeneous sample in the future (e.g. weightlifters).

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