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Research Article

Effects of the conventional deadlift and Romanian deadlift on muscle activation and joint angles at a submaximal intensity

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Abstract

In strength and conditioning, exercise selection and intensity are pivotal for designing resistance training programmes. The conventional deadlift (CD) and Romanian deadlift (RDL) are exercises targeting the lower limbs. Despite being similar, differences exist and comparative studies between CD and RDL remain scarce. This study (i) assessed if the biceps femoris (BF) exhibited greater activation during the RDL, and (ii) determined if the vastus lateralis (VL) and BF showed increased activation during the CD. Fifteen active adults participated in the study, with EMG sensors placed on the VL and BF and markers for 2D motion analysis in the sagittal plane. Maximal voluntary contraction (MVC) data were collected for both lifts at 70% of the RDL 1RM. Five repetitions at 50% of the RDL 1RM were tested for EMG and 2D motion analysis. Data were analysed using paired t-tests and Wilcoxon signed-rank tests. Results revealed higher VL activation in the CD ($P < 0.05$), with no significant difference in BF activation. No differences were observed in hip angles at mid-thigh and knee height ($P > 0.343$), but differences were noted at the bottom position. Knee angles differed significantly during ascent and descent at mid-thigh ($P < 0.027$), while ankle differences were evident at knee height and the bottom position ($P < 0.12$). Ranges of motion differed for all joints ($P < 0.002$). In conclusion, this study found no difference in BF activation but greater VL activation during the CD.

Keywords: deadlift, injury, joint angles, muscle activation, Romanian deadlift.

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Introduction

Exercise selection and an appropriate loading stimulus over time are the cornerstones of an effective resistance training programme. Many tools can be implemented to achieve strength training goals for those delivering resistance training programmes, including the “Big 3”: the squat, bench press and the conventional deadlift (CD). The CD is a compound exercise prescribed to increase the strength of the posterior chain muscles (gluteus, hamstrings, erector spinae) and the quadriceps (Parker, 2008). However, in sports like CrossFit, where high-intensity and fast-paced training is encouraged, the loss of form may increase the risk of injury due to increased stress on the lumbopelvic region. A systematic review by Alekseyev et al. (2020) found that within 12 months, 18% of CrossFit injuries occurred while performing a CD. Hexagonal deadlifts have been popularised due to the design of the barbell facilitating a shift of focus from the lower back, hips, and hamstrings to the quadriceps thus reducing the stress on the lumbopelvic region (Camara et al., 2016). The mixed-grip deadlift is another popular variant used in resistance training programmes, as grip strength is a limiting factor (Pratt et al., 2020). The Romanian deadlift (RDL) is a variant of the CD. Typically, athletes and gym-goers use the RDL to strengthen the hamstrings, paraspinal and gluteal muscles (Piper & Waller, 2001). In sports, the RDL helps to teach athletes the Olympic lifts (Frounfelter, 2000) and improves the hamstring-quadricep ratio (Veeck et al., 2023). The RDL is under-researched in favour of the CD; the movements are mechanically similar and often mistaken for one another (Lee et al., 2018).

Using electromyography (EMG) allows researchers to investigate muscle activation. Specifically, surface electromyography (sEMG) allows the researcher to collect data without discomfort or interference to the athlete. The most researched muscles during a CD are the biceps femoris (BF), gluteus maximus, vastus lateralis (VL), and erector spinae, with the CD and stiff-legged deadlift (SLD) being the most investigated variants of the deadlift (Martín-Fuentes et al., 2020).

Studies comparing the CD and RDL are limited; there is currently one study that directly compared the two (Lee et al., 2018). This research is important as it can help inform strength and conditioning coaches, athletes, and gym-goers of the potential benefits and injury risks associated with these lifts. This study will be the first to examine and compare VL activity directly between the CD and RDL. This study aims to compare the CD and RDL at submaximal intensity in recreational athletes. Using surface EMG on the VL and BF and 2D motion analysis of the lower limb, we aim to determine if (i) the BF activation is greater during the RDL and (ii) if there is a higher activation of both VL and BF during the CD.

Methods

Participants

Fifteen recreationally active, healthy adults (11 males; 4 females; 25 ± 5 years; 1.75 ± 0.09 m; 80.4 ± 12.3 kg) volunteered to participate in this study. Participants were excluded if they experienced any musculoskeletal injuries within six months of participating. Inclusion criteria included 3 to 5 years of experience with the CD and RDL, and participants were asked not to partake in strenuous exercise two days before the experiment. All participants were provided with details of the experiment and the associated risks and completed a physical activity readiness questionnaire (PAR-Q) before providing informed consent. The study received ethical approval from the Northumbria University Faculty of Health and Life Science Ethics committee.

Protocol

After the participants' descriptive data (sex, stature, mass) were collected, they were allocated to groups 1 or 2, which changed the order in which the movements were performed to eliminate order bias. RDL 1RM was self-reported; if the participant did not know their 1RM, the Brzycki formula was used to predict it (predicted 1RM = w / (1.0278 – 0.0278x; w = weight lifted; x = number of repetitions performed). The Brzycki formula is valid when the number of repetitions is <10 (Brzycki, 1993). The load was rounded to the nearest 5 kg due to the lack of microweights. Figure 1 shows the protocol for the warm-up. Participants were asked to perform the warm-up and protocol barefoot, so shoe type did not influence the results. The warm-up included a mobility circuit consisting of five movements performed for 40 seconds, with a 20-second transition for one circuit. The barbell complex was performed with an empty standard barbell (20 kg) for five repetitions per movement and repeated for 2-3 sets with a 1-minute rest between sets. The barbell complex provided an opportunity to assess the participant's ability to perform the lifts correctly. The barbell load was progressively loaded to 70% 1RM of the RDL for a smooth transition to collect maximal voluntary contraction (MVC) data. The RDL 1RM value was chosen because a lower load is required for an RDL than a CD, as the relative intensity between the lifts differs.

Following the warm-up, MVC data was collected for the CD and RDL as 70% 1RM of the RDL to normalise EMG data. Next, the EMG and 2D video capture data were recorded for five repetitions using 50% of RDL 1RM for both CD and RDL. Participants were not coached to capture their typical technique during the test after evaluating their ability to perform the lifts during the warm-up.

Figure 1. Warm-up protocol. Mobility circuit; 40 s work, 20 s transition, barbell complex; 3 sets of 5 repetitions per movement with an empty barbell with one-minute rest between sets, progressive ramp up; load calculated as % of RDL 1RM.

Electromyography

EMG analysis was performed using a wireless surface system (sEMG, Delsys Trigno Research+, Delsys Inc, Natick, MA, USA) at a sampling rate of 2,000 Hz. Before sensor placement, the participants' skin was prepared by shaving and cleaning the area with an alcohol wipe after the warm-up to reduce interference in the EMG recording. Wireless sEMG sensors were placed on the VL and BF of the dominant limb following SENIAM guidelines (Konrad, 2006). Adhesive tape was used to secure the sensors to the skin and reduce movement artefacts. This study did not include the erector spinae and gluteus maximus due to ethical considerations regarding privacy and crosstalk with other muscles was weak during pilot testing.

An amplitude analysis was conducted on the raw EMG data using EMGWorks (v4.8, Delsys Inc, Natick, MA, USA). A root mean squared (RMS) filter was applied to the raw data using a 0.125 s window length and a 0.0625 s window overlap. If needed, a high-pass filter was applied to remove movement artefacts. 70% MVC was used to normalise the data, and the mean of the peak RMS value from each repetition was used in statistical data analysis. EMG from one participant and VL data from another were excluded from the analysis due to corrupt data.

2D Video Capture

Five coloured markers were placed on the acromion process, greater trochanter, lateral epicondyle of the knee, and the 5th metatarsal of the participant's dominant side. A video camera (Sony, Handycam HDR-CX240) and tripod were set to the researcher's hip height and captured in the sagittal plane. The ascending and descending phases were split into the bottom position, knee height, and mid-thigh to simplify comparisons (see Figure 2). Angles from five repetitions at the hip, knee, and ankle at each phase and position were analysed using open-source video analysis software (Kinovea v0.9.5). Kinovea is valid and has good intra-rater reliability when measuring angles at the hip, knee, and ankle (Puig-Divi et al., 2019). One repetition was missing from the video data for the CD due to a counting error.

Hip angles were measured relative to the acromion process and the lateral epicondyle of the femur; knee angles were measured relative to the greater trochanter of the femur and the lateral malleolus of the ankle; ankle angles were measured relative to the lateral epicondyle of the femur and the 5th metatarsal of the foot. All angles were measured in the sagittal plane, with 180° representing a full extension of the hip and knee and 90° representing a neutral foot position. The mean of five repetitions for each variable was used in the statistical analysis. The ROM for each joint was calculated by the difference between the bottom and mid-thigh positions for each phase.

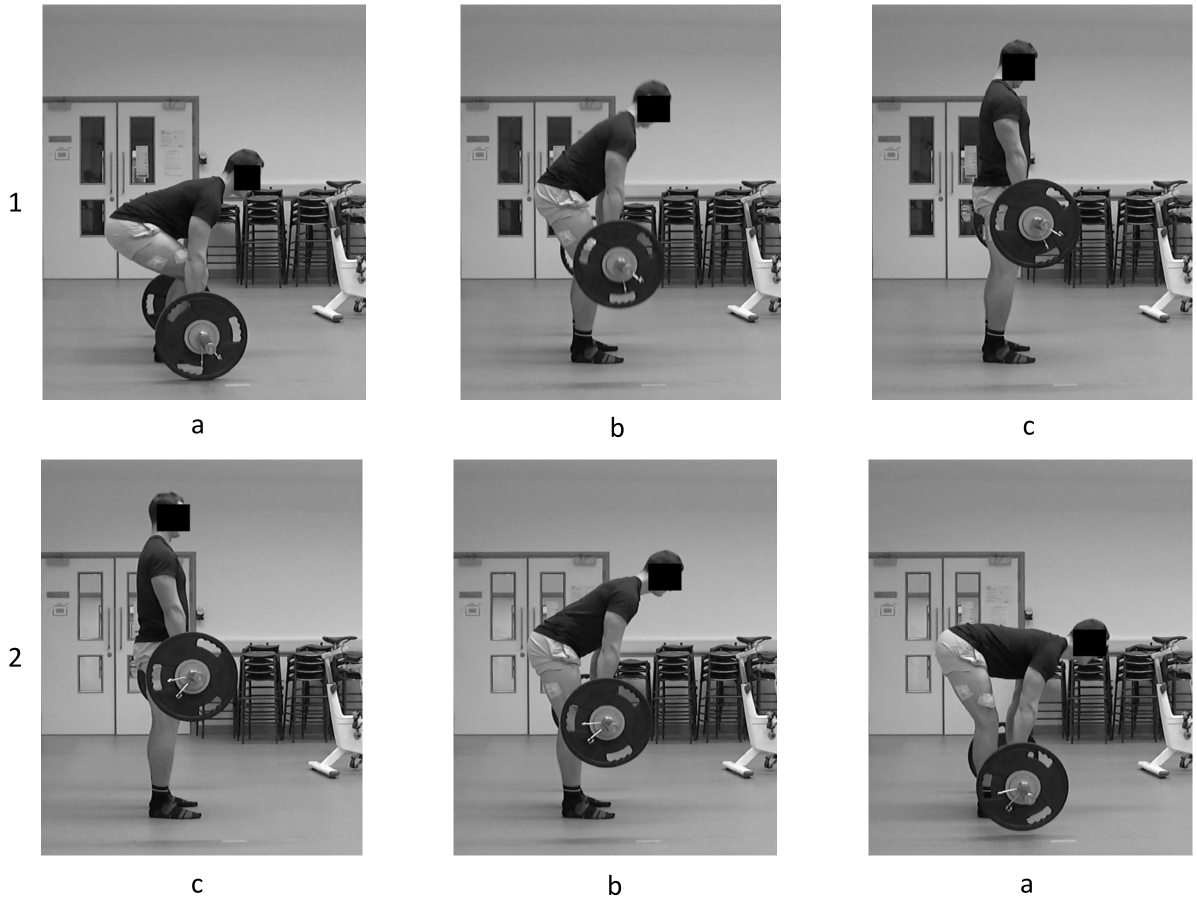

Figure 2. Positions for the CD and RDL: 1 = conventional deadlift; 2 = Romanian deadlift; a = bottom position; b = knee height; c = mid-thigh.

Data Analysis

For this within-subject design, paired t-tests were conducted to compare electromyographic variables (VL and BF) and the ascending and descending phases for joint angles and ROM at the hip, knee, and ankle for the CD and RDL. Before running the paired t-test, statistical assumptions were checked for normality using the Shapiro-Wilk test. Where statistical assumptions were violated (n = 3), a non-parametric test was conducted using a Wilcoxon signed-rank test. All statistical tests were performed using IBM SPSS Statistics (v28 Armonk, NY, USA) with the level of significance set at $p < 0.05$ for all tests.

Results

Electromyography

Table 1 shows the results for EMG activity. The results suggest greater activation of the VL in the CD (87.5 ± 26.1 vs 59.2 ± 24.7%; $P < 0.001$). However, there was no difference in the BF between the CD and RDL (65.9 ± 23.4 vs 77.9 ± 33.2%; $P = 0.244$).

Table 1. EMG results from the vastus lateralis and biceps femoris.

	Mean (SD)					
	Conventional Deadlift	Romanian Deadlift	Mean Diff	*t*	*df*	*P*
Vastus Lateralis (%)	87.5 (26.1)	59.2 (24.7)	-28.3	7.331	12	0.001*
Biceps Femoris (%)	65.9 (23.4)	77.9 (33.2)	12.0	-1.220	13	0.244

Note: Mean and SD expressed as a percentage of 70% MVC. * Denotes statistical significance between CD and RDL; $P < 0.05$.

Joint Angles and Range of Motion

Angles at the hip (see Table 2) suggest no difference at mid-thigh between the CD and RDL whilst ascending or descending (ascent; 173.3 ± 5.6 vs 172.2 ± 5.9°, descent; 173.3 ± 5.6 vs 171.8 ± 5.8°, $P \geq 0.343$). Furthermore, there were no differences in knee height whilst ascending or descending (ascent; 113.0 ± 6.2 vs 112.9 ± 5.3°, descent; 114.4 ± 6.0 vs 114.6 ± 5.2°, $P \geq 0.892$). Angles at the bottom position, for both ascending and descending phases were different (ascent; 54.5 ± 6.4 vs 64.6 ± 8.6°; $P = 0.002$; descent; 54.4 ± 6.9 vs 64.6 ± 8.9°; $P = 0.002$).

Angles at the knee (Table 3) suggest a difference between ascending and descending at mid-thigh (ascent; 173.9 ± 6.5 vs 170.9 ± 6.8°, descent; 173.5 ± 6.7 vs 170.3 ± 6.9°, $P < 0.027$) and bottom positions (ascent; 107.1 ± 13.6 vs 137.3 ± 9.4°, descent; 111.8 ± 16.3 vs 137.3 ± 9.4°, $P < 0.001$). There was no difference between ascending and descending at knee height (ascent; 154.7 ± 5.0 vs 156.9 ± 5.2°, descent; 154.7 ± 4.9 vs 157.4 ± 5.2°, $p > 0.056$).

Table 2. Hip angles between the CD and RDL.

		Mean (SD)					
		Conventional Deadlift	Romanian Deadlift	Mean Diff	*t*	*df*	*P*
Mid-thigh (°)	Ascent	173.3 (5.6)	172.2 (5.9)	-1.2	0.435	14	0.670
	Descent	173.3 (5.6)	171.8 (5.8)	-1.5	0.982	14	0.343
Knee Height (°)	Ascent	113.0 (6.2)	112.9 (5.3)	-0.1	0.028	14	0.978
	Descent	114.4 (6.0)	114.6 (5.2)	0.2	0.982	14	0.892
Bottom Position (°)	Ascent	54.5 (6.4)	64.6 (8.9)	10.1	115	-	0.002*[a]
	Descent	54.4 (6.9)	64.6 (8.9)	10.3	-3.957	14	0.001*

Note: * Denotes statistical significance between CD and RDL; P < 0.05. [a] Denotes data not normally distributed and analysed with Wilcoxon signed-rank test.

Table 3. Knee angles between the CD and RDL.

		Mean (SD)					
		Conventional Deadlift	Romanian Deadlift	Mean Diff	*t*	*df*	*P*
Mid-thigh (°)	Ascent	173.9 (6.5)	170.9 (6.8)	-3.0	18	-	0.017* [a]
	Descent	173.5 (6.7)	170.3 (6.9)	-3.1	21	-	0.027* [a]
Knee Height (°)	Ascent	154.7 (5.0)	156.9 (5.2)	2.2	-1.067	14	0.169
	Descent	154.7 (4.9)	157.4 (5.2)	2.8	-2.085	14	0.056
Bottom Position (°)	Ascent	107.1 (13.6)	137.3 (9.4)	30.2	-7.646	14	0.001*
	Descent	111.8 (16.3)	137.3 (9.4)	25.5	-5.540	14	0.001*

Note: * Denotes statistical significance between CD and RDL; P < 0.05. [a] Denotes data not normally distributed and analysed with Wilcoxon signed-rank test.

Angles at the ankle (see Table 4) showed no difference with ascending or descending between CD and RDL at mid-thigh (ascending; 112.9 ± 8.5 vs 112.7 ± 8.1°, descending; 113.6 ± 8.4 vs 112.6 ± 8.3°, P > 0.493). There were differences between the CD and RDL for ascending (111.4 ± 6.9 vs 115.2 ± 6.5°, P = 0.002) and descending (112.6 ± 6.6 vs 115.6 ± 6.9°, P = 0.012) at knee height. Furthermore, differences were found for ascending (96.5 ± 8.8 vs 110.8 ± 9.6°, P = 0.001) and descending (97.9 ± 10.2 vs 110 ± 8.1°, P = 0.001) at the bottom position.

Differences for ROM were consistent (see Table 5); ROM at the hip (ascent; 117.8 ± 11.1 vs 107.7 ± 8.9°, P = 0.002, descent; 118.1 ± 12.1 vs 107.2 ± 8.6°, P = 0.001), knee (ascent; 65.2 ± 13.9 vs 38.3 ± 14.5°, P = 0.001, descent; 60.0 ± 12.6 vs 37.8 ± 14.3°, P = 0.001), and ankle (ascent; 15.3 ± 5.9 vs 5.9 ± 6.1°, P = 0.002, descent; 15.2 ± 6.7 vs 6.3 ± 6.3°, P = 0.001).

Table 4. Ankle angles between the CD and RDL.

		Mean (SD)					
		Conventional Deadlift	Romanian Deadlift	Mean Diff	*t*	*df*	*P*
Mid-thigh (°)	Ascent	112.9 (8.5)	112.7 (8.1)	-0.2	0.199	14	0.845
	Descent	113.6 (8.4)	112.6 (8.3)	-0.9	0.704	14	0.493
Knee Height (°)	Ascent	111.4 (6.9)	112.9 (8.3)	3.8	-3.866	14	0.002*
	Descent	112.6 (6.6)	115.8 (6.9)	3.0	-2.903	14	0.012*
Bottom Position (°)	Ascent	96.5 (8.8)	110.8 (9.6)	14.3	115.000	-	0.002*[a]
	Descent	97.9 (10.2)	110.0 (8.1)	12.0	-4.043	14	0.001*

Note: * Denotes statistical significance between CD and RDL; $p < 0.05$. [a] Denotes data not normally distributed and analysed with Wilcoxon signed-rank test.

Table 5. Range of motion at the hip, knee, and ankle.

		Mean (SD)					
		Conventional Deadlift	Romanian Deadlift	Mean Diff	*t*	*df*	*P*
Hip (°)	Ascent	118.8 (8.8)	107.5 (10.8)	-11.3	3.789	14	0.002*
	Descent	119.0 (9.3)	107.2 (10.6)	-11.8	4.194	14	0.001*
Knee (°)	Ascent	66.8 (13.9)	33.6 (12.8)	-33.2	8.637	14	0.001*
	Descent	61.7 (15.4)	33.0 (12.7)	-28.6	6.239	14	0.001*
Ankle (°)	Ascent	16.4 (7.1)	2.5 (7.4)	-14.0	5.612	14	0.001*
	Descent	15.6 (8.7)	3.4 (6.8)	-12.2	3.996	14	0.001*

Note: * Denotes statistical significance between CD and RDL; $P < 0.05$.

Discussion

This study aimed to determine (i) if there is a difference in the BF between the CD and RDL, (ii) if there was greater activation of the VL and BF in the CD, and (iii) if an injury was more likely to occur in the CD or RDL using joint angles and ROM of the hip, knee, and ankle. The key findings of this current study are as follows: 1) There were no differences in BF activation between the CD and RDL. 2) Activation of the VL during the CD differed from the RDL and 3) ROM at the hip, knee, and ankle during the CD was greater than the RDL.

Electromyography

Firstly, the RDL is a popular movement to train the hamstrings; however, our findings agree with those of Lee et al. (2018), who found no difference in BF activation between the CD and RDL. Positioning of the hip has been shown to influence the ROM at the knee and increase the moment arm of the BF (Hamill et al., 2022). The BF activity could be due to the length-tension relationship being influenced by the interaction between the hip and knee positioning. Furthermore, Bezerra et al. (2013) suggest this result could be due to the hamstrings acting as knee stabilisers during the RDL and the SLD. Conversely, it has been suggested that the hamstrings generate the greatest force when flexed at 90°, reducing by 50% when reaching full extension (Hamill et al., 2022). The differences in knee ROM between the CD and RDL (ascent = 67 vs 34°; descent = 62 vs 33°) suggest more time under tension, which could explain why BF activity during the CD was not different. Moreira et al. (2023) report similar results whereby the BF is highly activated at knee height during the CD. Due to the lack of EMG data comparing the CD and RDL, findings by Coratella et al. (2022) were included, who found no difference in BF activation between the RDL and SLD, so they could reasonably be used for comparisons with the CD.

Secondly, this study is the first to compare VL activity between the CD and RDL, making direct comparisons between studies impossible. Lee et al. (2018) compared EMG activity for the rectus femoris between the CD and RDL. Although it is a quadricep muscle, it is a biarticular muscle with attachments at the hip and knee, unlike the VL, whose attachments are at the greater trochanter and the knee, potentially inflating EMG activity. VL results agree with Bezerra et al. (2013), who compared the CD with the SLD and found VL activation peaked within the first 20° during the ascent of a CD. Interestingly, Koderi et al. (2020) studied the differences in BF and VL activation during the RDL with different stance widths. BF activation did not change; however, with a wide stance, VL activity increased. This could be attributed to a change in knee angles for the different stance widths.

Joint Angles and Range of Motion

Joint angles at the mid-thigh position during ascent and descent showed no significant difference at the hip or ankle. This finding is not surprising, as the hip should be close to full extension and the ankle in a neutral position. However, the knee angle was significantly different. This could be due to the participants anticipating the hip flexion for the RDL before the lift was completed. The descent during the RDL is initiated by hip flexion, while knee flexion is limited between mid-thigh and knee height positions compared to the CD (13 vs 19°).

Angles at knee height showed no difference at the hip and knee. This study's findings are similar to those of Piper and Waller (2001), Lee et al. (2018), and McAllister et al. (2014), who observed knee flexion between 15 to 30° for the RDL. Unlike the previous studies, this study did not standardise technique, stance width or knee angle; however, standardisation was implemented by asking lifters to perform the lifts barefoot. Although footwear has been found not to improve performance, it has been shown to manipulate joint angles and ground reaction force (La Marche, 2019; Valenzuela et al., 2021). There was a significant difference at the ankle, with the CD showing greater angles during ascent and descent. The RDL's starting position is at the mid-thigh and descends to the bottom position; depending on the individual's hamstring flexibility, the ankle may not need to dorsiflex following the knee height position. In the CD (during the ascent), to allow a vertical bar path and avoid horizontal displacement of the bar, the shank needs to plantarflex.

Angles at the bottom position for the hip, knee, and ankle differed significantly. The significant differences in knee angle at the bottom position during the descent agree with Lee et al. (2019), who suggest that the difference in knee flexion during the RDL at the bottom position could be due to the lack of flexibility of the hamstrings. However, the previous study only studied flexion angles during the CD and RDL. Escamilla et al. (2000) also reported knee angles greater than the hip angle during the CD at the bottom position, suggesting the hips will be above the knees at the start of the CD and significantly different from the RDL in this current study. When studying muscle forces during the CD, Schellenberg et al. (2017) reported a ROM of 70 to 100° of knee flexion is required for the optimal activation of the VL. The findings of this current study from the ascending phase were very close to this study's observation (65°). Furthermore, the smaller knee ROM and lower VL activation of the RDL are consistent with the previous study, which compared the CD to the good morning (a movement mechanically similar to the RDL).

Limitations

This study had several limitations. Due to the confines of 2D motion capture in the sagittal plane, weight plates and loose clothing obscured or moved the coloured markers placed on the participants at mid-thigh and knee height positions. Therefore, guidelines were drawn on the video to estimate the anatomical landmarks and improve reliability. Furthermore, 3D motion capture is the gold standard method of collecting kinematic data and may have provided more accurate and reliable data, but the set-up may have been a burden to the participants. EMG has its own set of limitations. SENIAM guidelines were followed to reduce the cross-talk between muscles. Participants were shaved, and adhesive tape was applied after the warm-up to secure the sensors to the skin. However, some data contained questionable signals, possibly due to movement artefacts induced by weight plates hitting the floor. Noise signals due to electrical equipment could not be avoided and may have influenced data. Although measuring the 1RM for the RDL may have been more reliable, the Brzycki formula was used to estimate 1RM values to minimise the risk of injury to participants who may have never tested their 1RM before (Brzycki, 1993). This current study investigated the lifts in the sagittal plane, limiting the investigation of potential knee injuries, such as those involving knee valgus.

Future Directions

Future research could explore additional muscles and joints in the lower and upper extremities, such as the paraspinal, gluteal, and forearm muscles. Additionally, comparing the grip types between the lifts may be of interest. Furthermore, a consistent EMG normalisation method across the research would also be beneficial. The different methods make comparing findings in the research challenging. 3D motion analysis in conjunction with sEMG could provide more insight into muscle activity and intermuscular coordination during different phases of the lifts. Additionally, tracking the bar path during the lifts could help inform lifters of the impact on muscle activation and risk of injury.

Conclusion

Firstly, the CD and RDL are effective movements for training the BF. This study's protocol was based on the RDL 1RM; however, the RDL elicited some differences in the EMG response and may be a better option if the lifter aims to improve their hamstrings-quadriceps ratio without adding the back squat. Finally, although the CD may be more beneficial for concurrently training the VL and BF, neuromuscular fatigue may occur quicker than during the RDL with the same load. This research has highlighted the difference between VL activity between the CD and RDL. Strength and conditioning coaches and recreational athletes could use the CD when adequately recovered, and increasing strength or rehabilitating the knee is the goal.

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