An electromyographic analysis of sumo and conventional style deadlifts

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ABSTRACT

ESCAMILLA, R. F., A. C. FRANCISCO, A. V. KAYES, K. P. SPEER, and C. T. MOORMAN, III. An electromyographic analysis of sumo and conventional style deadlifts. *Med. Sci. Sports Exerc.*, Vol. 34, No. 4, pp. 682–688, 2002. **Purpose:** Strength athletes often employ the deadlift in their training or rehabilitation regimens. The purpose of this study was to compare muscle activity between sumo and conventional style deadlifts, and between belt and no-belt conditions. **Methods:** Six cameras collected 60-Hz video data and 960-Hz electromyographic data from 13 collegiate football players who performed sumo and conventional deadlifts with and without a lifting belt, employing a 12-RM intensity. Variables measured were knee angles and EMG measurements from 16 muscles. Muscle activity were averaged and compared within three 30° knee angle intervals from 90 to 0° during the ascent, and three 30° knee angle intervals from 0 to 90° during the descent. **Results:** Overall EMG activity from the vastus medialis, vastus lateralis, and tibialis anterior were significantly greater in the sumo deadlift, whereas overall EMG activity from the medial gastrocnemius was significantly greater in the conventional deadlift. Compared with the no-belt condition, the belt condition produced significantly greater rectus abdominis activity and significantly less external oblique activity. For most muscles, EMG activity was significantly greater in the knee extending intervals compared with the corresponding knee flexing intervals. Quadriceps, tibialis anterior, hip adductor, gluteus maximus, L3 and T12 paraspinal, and middle trapezius activity were significantly greater in higher knee flexion intervals compared with lower knee flexion intervals, whereas hamstrings, gastrocnemius, and upper trapezius activity were greater in lower knee flexion intervals compared with higher knee flexion intervals. **Conclusions:** Athletes may choose to employ either the sumo or conventional deadlift style, depending on which muscles are considered most important according to their training protocols. Moderate to high co-contractions from the quadriceps, hamstrings, and gastrocnemius imply that the deadlift may be an effective closed kinetic chain exercise for strength athletes to employ during knee rehabilitation. **Key Words:** EMG, MUSCLE ACTIVITY, WEIGHT TRAINING, POWERLIFTING, REHABILITATION, STRENGTH ATHLETE, FOOTBALL

Strength athletes, such as American football players and powerlifters, often employ the barbell deadlift in their weight-training regimen or rehabilitation program, such as during the late stages of anterior cruciate ligament (ACL) rehabilitation. These athletes use the deadlift to enhance hip, thigh, and back strength. The starting position for the deadlift is with the lifter in a squat position with the knees and hips flexed approximately 80–100°, arms straight and pointing down, and an alternating hand grip used to hold a barbell positioned in front of the lifter's feet (6). The barbell is then lifted upward in a continuous motion by extending the knees and hips until the lifter is standing erect with knees locked and the shoulders thrust back. From this position, the barbell is slowly lowered back to the ground by flexing the knees and hips. This deadlift motion can be performed using either a conventional or sumo style. The primary differences between these two styles are that the feet are positioned further apart and turned out more in the sumo style, and the arms are positioned inside the knees for the sumo style and outside the knees for the conventional style. Additional kinematic comparisons between sumo and conventional deadlifts have been previously described (6,17).

The efficacy of one deadlift style over another is unclear. An athlete will choose a deadlift style based on several factors, such as comfort, muscle involvement, and personal preference. For example, an American football player with disproportionately stronger quadriceps relative to their hamstrings may choose a deadlift style they believe evokes a relatively greater hamstring involvement and a relatively less quadriceps involvement. In addition, one deadlift style may develop the gluteal and hip adductor muscles to a greater extent than the other deadlift style. Therefore, muscle involvement and development may be determining factors in choosing one technique over another. However, electromyographic data, which provides insights into muscle involvement, are not yet available for sumo and conventional deadlifts.

Four studies have compared biomechanical parameters between sumo and conventional deadlifts (2,6,7,17). McGuigan and Wilson (17) performed a kinematic analysis during regional powerlifting competition and reported a more upright trunk, less hip flexion at barbell liftoff, and a greater shank range of motion in the sumo deadlift com-

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pared with the conventional deadlift. Cholewicki et al. (2) quantified lumbar loads and hip and knee moments during a national powerlifting championship and found significantly greater L4–L5 shear forces and moments in the conventional group, whereas hip and knee moments were not significantly different between the two deadlift styles. Escamilla et al. (6,7) performed a three dimensional (3-D) kinematic and kinetic analysis during a national masters powerlifting championship (6) and during the Special Olympics World Games (7). Several significant differences in joint and segment angles, mechanical work, and ankle, knee, and hip moments and moment arms were found between sumo and conventional deadlifts. Ankle dorsiflexor moments were generated in the sumo deadlift, whereas ankle plantar flexor moments were generated in the conventional deadlifts. Knee extensor moments were significantly greater in the sumo deadlift, whereas there were no significant differences in hip extensor moments between the sumo and conventional deadlifts.

It was the purpose of this study to compare muscle activity from leg, thigh, hip, and trunk musculature between sumo and conventional deadlifts. From deadlift kinetic data (6,7), it was hypothesized that knee extensor and ankle dorsiflexor muscle activity would be significantly greater in the sumo deadlift, ankle plantar flexor activity would be significantly greater in the conventional deadlift, hip extensor activity would not be significantly different between sumo and conventional deadlifts, and back extensor activity would be significantly greater in the conventional deadlift.

Because strength athletes train the sumo and conventional deadlifts both with and without a training belt, it was also the purpose of this study to compare muscle activity during the deadlift both with and without a training belt. Several studies have shown an increase in intra-abdominal pressure (IAP) when using a weight-belt during lifting movements (9,13,14,16,19), which may affect trunk muscle activity. Differences in trunk musculature have been reported during lifting between belt and no-belt conditions (14,19). Therefore, it was hypothesized that there would be differences in trunk musculature during the deadlift between belt and no-belt conditions.

MATERIALS AND METHODS

Subjects. Thirteen Division I-A collegiate football players served as subjects. All subjects were familiar with and had previously performed both the sumo and conventional deadlifts in their training regimen. Mean age, body mass, and body height were 20.1 ± 1.3 yr, 102.8 ± 16.1 kg, and 186.6 ± 7.5 cm, respectively. The mean load lifted was 123.1 ± 18.6 kg. Mean foot angle (i.e., mid-foot abduction, defined as 0° with the midline of the foot pointing straight ahead in the same direction the subject was facing), stance width (inside heel to inside heel), and hand width (inside hand to inside hand) were 25.1 ± 8.7°, 64.9 ± 16.9 cm, and 25.3 ± 7.7 cm, respectively, for the sumo deadlift, and 7.0 ± 3.2°, 32.7 ± 5.3 cm, and 48.0 ± 8.7 cm, respectively, for the conventional deadlift. All subjects signed a human consent form before their participation.

Data collection. Spherical plastic balls (3.8 cm in diameter) covered with reflective tape were attached to adhesives and positioned over the following bony landmarks: a) medial and lateral malleoli of the left foot, b) upper edges of the medial and lateral tibial plateaus of the left knee, c) posterior aspect of the greater trochanters of the left and right femurs, d) acromion process of the left shoulder, and e) third metatarsal head of the left foot. Six electronically synchronized high-speed charged couple device video cameras were strategically positioned around each subject, and centroid images from the reflective markers were transmitted directly into a motion analysis system (Motion Analysis Corporation, Santa Rosa, CA).

Electromyography (EMG) was utilized to quantify muscle activity. EMG data were quantified with a 16 channel Noraxon Telemyo EMG telemetry unit (Noraxon U.S., Inc., Scottsdale, AZ). The amplifier bandwidth frequency ranged from 16 to 500 Hz, with an input voltage of 12 VDC at 1.5 A. The input impedance of the amplifier was 20,000 kΩ, and the common-mode rejection ratio was 130 Db. The skin was prepared by shaving, abrading, and cleaning.

Neuroline (Medicotest Marketing, Inc., Ballwin, MO) disposable surface electrodes (type 720-00-S) were used to collect EMG data. These oval shaped electrodes (22 mm wide and 30 mm long) were placed in pairs along the longitudinal axis of each muscle or muscle group tested, with a center-to-center distance between each electrode of 2–3 cm. One electrode pair was placed on each the following muscles in accordance with procedures from Basmajian and Blumenstein (1) and Cram and Kasman (3): 1) rectus femoris; 2) vastus lateralis; 3) vastus medialis; 4) lateral hamstring (biceps femoris); 5) medial hamstrings (semitendinosus/semimembranosus); 6) lateral gastrocnemius; 7) medial gastrocnemius; 8) tibialis anterior; 9) hip adductors (adductor longus, adductor magnus, and gracilis); 10) gluteus maximus; 11) L3 paraspinals; 12) T12 paraspinals; 13) middle trapezius; 14) upper trapezius; 15) rectus abdominis; and 16) external obliques. EMG and video data were synchronized by the motion analysis system, with EMG data sampled at 960 Hz and video data sampled at 60 Hz. Because bilateral symmetry has been demonstrated during the deadlift (6), EMG and video data were collected and analyzed only on the subject's left side.

During testing, each subject performed four variations of the deadlift, each performed in a randomized order: a) sumo deadlift with belt, b) sumo deadlift without belt, c) conventional deadlift with belt, and d) conventional deadlift without belt. A heavy-duty weight-belt (14) consisting of three layers of leather 1.0 cm thick and 10.0 cm wide throughout its length was employed by all subjects and tightened in accordance to individual preference. Each subject employed the same weight for each of the four deadlift variations, which was equivalent to their 12-repetition maximum (12 RM) weight they currently were using in the hypertrophy phase of a periodization regimen. An 8–12 RM is a common repetition scheme for muscle hypertrophy (25) and is also a common repetition scheme during knee rehabilitation. A standard 20.5-kg Olympic barbell and Olympic disks were used during the deadlift. All subjects performed two to three warm-up sets in preparation for testing. Just before performing each deadlift variation, each subject's stance width and foot angle (i.e., mid-foot abduction) were measured. Each subject performed four repetitions for each exercise variation in a slow and continuous manner (both during the ascent and descent), similar to how they performed the deadlift during their training regimen. Data collection was initiated at the end of the first repetition and continued throughout the final three repetitions of each set. Therefore, three distinct trials were collected for each deadlift variation. Between each repetition, the subjects were instructed to pause approximately 1 s to provide a clear separation between trials. Each subject rested long enough between exercise variations to completely recover from the previous set (approximately 3–4 min). Fatigue was assumed to be negligible due to the submaximal weight lifted, the low lifting intensity, the low number of repetitions and sets compared with their normal training session, a sufficient rest interval between sets, and the high fitness level of the subjects. All subjects acknowledged that fatigue did not adversely affect their ability to perform any of the exercise variations.

Subsequent to exercise testing, EMG data from the muscles tested were then collected during maximum voluntary isometric contractions (MVIC) to normalize the EMG data collected during the four deadlift variations (4). MVICs were performed after exercise testing because the muscles were now warmed up but not fatigued. Three 5-s MVIC trials were collected for each muscle group in a randomized manner, with approximately a 1-min rest interval between each MVIC. Methods and positions used during MVICs, which are common positions used in manual muscle testing to isolate individual muscles or muscle groups, have previously been described (4,11). Because all the muscle groups were randomly tested, fatigue was assumed to be minimal. Each highly trained subject acknowledged that fatigue did not adversely affect their ability to perform maximal-effort MVICs.

Data reduction. Video images for each reflective marker were automatically digitized in 3-D space with Motion Analysis EVa software, utilizing the direct linear transformation method (4). Testing of the accuracy of the calibration system resulted in reflective balls that could be located in 3-D space with an error less than 1.0 cm. The raw position data were smoothed with a double-pass fourth-order Butterworth low-pass filter with a cut-off frequency of 6 Hz (4). Knee joint angles were calculated throughout the lift using EVa software. Knee angle (KA) was defined as 0° when the knees were fully extended.

EMG data for each deadlift trial and the highest 1 s of each MVIC trial were rectified and averaged in a 0.01-s moving window. Data for each muscle tested were normalized as a percentage of the subject's highest corresponding MVIC trial over the entire KA range of each deadlift variation. The upward (ascent) phase of the deadlift was divided into three 30° intervals from 90 to 0° KA: a) 90–61°, b) 60–31°, and c) 30–0°. Similarly, the downward (descent) phase of the deadlift was divided into three 30° intervals from 0 to 90°KA: a) 0–30°, b) 31–60°, and c) 61–90°. Normalized EMG data for each muscle were then averaged over each of the three ascent and three descent KA intervals for each of the three repetitions (trials) and four deadlift variations. The three trial average for each muscle and KA interval was then used in the statistical analysis.

Statistical analysis. A three-factor repeated measures analysis of variance ($P < 0.01$) was employed to examine the interaction effect and test for main effects of: a) two deadlift styles (sumo vs conventional); b) two belt conditions (belt vs no-belt); and c) six knee angle intervals (90–61°, 60–31°, 30–0°, 0–30°, 31–60°, and 61–90°). *Post hoc* comparisons were made using the Tukey test ($P < 0.01$) to evaluate the significance between pairwise comparisons.

RESULTS

Each repetition during the sumo and conventional deadlift took between 2.50 and 2.75 s to complete (discounting the slight pause at the end of the ascent before the descent), with sumo ascent and descent times of 1.24 ± 0.15 s and 1.32 ± 0.24 s, respectively, and conventional ascent and descent times of 1.30 ± 0.18 s and 1.43 ± 0.21 s, respectively. Several small but significant EMG differences were observed between sumo and conventional deadlifts (Table 1). Compared with the conventional deadlift, the sumo deadlift had significantly greater EMG activity in the vastus lateralis, vastus medialis, and tibialis anterior but significantly less EMG activity in the medial gastrocnemius. Compared with the belt condition, the no-belt condition had significantly greater EMG activity in the rectus abdominis but significantly less EMG activity in the external obliques (Table 1). There were no significant interactions observed for all measurements.

For most muscles, EMG activity was significantly greater in the knee extending intervals compared with the corresponding knee flexing intervals (Table 1). Quadriceps, tibialis anterior, hip adductor, gluteus maximus, L3 and T12 paraspinal, and middle trapezius activity were significantly greater in higher knee flexion intervals (61–90°) compared with lower knee flexion intervals (0–30°), whereas hamstrings, gastrocnemius, and upper trapezius activity were greater in lower knee flexion intervals compared with higher knee flexion intervals (Table 1). Mean EMG patterns for select muscles during the deadlift are shown in Fig. 1A and B.

DISCUSSION

Our EMG results are supported by kinetic data from Escamilla et al. (6,7), who quantified ankle, knee, and hip moments during the sumo and conventional deadlifts. These authors, who conducted the only known study that quantified ankle moments between conventional and sumo deadlifts, reported that the sumo deadlift generated ankle dorsi-

TABLE 1. Electromyographic comparisons (mean ± SD) between sumo and conventional deadlifts (collapsed across all knee extending and knee flexing intervals and both belt conditions), between belt and no-belt (collapsed across all knee extending and knee flexing intervals and both deadlift styles), and between knee angle intervals (collapsed across both belt conditions and both deadlift styles); data were normalized and expressed as a percent of a maximum voluntary isometric contraction.

	Rectus Femoris	Vastus Lateralis	Vastus Medialis	Lateral Hamstring	Medial Hamstring	Lateral Gastrocnemius	Medial Gastrocnemius	Tibialis Anterior	Hip Adductors	Gluteus Maximus	L3 Paraspinal	T12 Paraspinal	Middle Trapezius	Upper Trapezius	Rectus Abdominis	External Obliques
Sumo	18 ± 13	48 ± 24*	44 ± 27*	29 ± 19	31 ± 23	34 ± 23	19 ± 17*	18 ± 9*	23 ± 16	37 ± 28	32 ± 16	33 ± 16	10 ± 9	43 ± 30	58 ± 27	58 ± 27
Conventional	19 ± 16	40 ± 22*	36 ± 25*	28 ± 19	27 ± 23	36 ± 25	26 ± 17*	13 ± 8*	24 ± 22	35 ± 27	32 ± 19	33 ± 19	9 ± 8	39 ± 36	60 ± 31	56 ± 24
Belt	18 ± 15	44 ± 23	39 ± 27	28 ± 19	28 ± 24	34 ± 24	23 ± 18	18 ± 11	23 ± 18	35 ± 27	30 ± 18	32 ± 18	9 ± 8	40 ± 32	63 ± 32**	53 ± 21**
No-belt	19 ± 15	45 ± 24	42 ± 28	29 ± 19	31 ± 21	36 ± 24	23 ± 19	19 ± 11	25 ± 19	37 ± 28	33 ± 19	35 ± 18	9 ± 8	42 ± 33	56 ± 26**	62 ± 26**
Knee extending (ascent)																
90–61° knee angle	36 ± 21	74 ± 20	71 ± 28	24 ± 11	24 ± 18	37 ± 29	23 ± 19	18 ± 6	23 ± 12	38 ± 28	31 ± 12	34 ± 14	16 ± 12	45 ± 32	65 ± 27	66 ± 24
60–31° knee angle	22 ± 13	63 ± 16	63 ± 30	49 ± 16	45 ± 24	51 ± 27	32 ± 21	16 ± 9	22 ± 18	32 ± 18	30 ± 18	31 ± 17	16 ± 11	76 ± 38	80 ± 32	75 ± 22
30–0° knee angle	17 ± 13	41 ± 23	35 ± 22	49 ± 15	45 ± 26	40 ± 21	31 ± 16	17 ± 12	24 ± 22	34 ± 22	32 ± 22	32 ± 22	9 ± 5	63 ± 30	79 ± 44	66 ± 25
Knee flexing (descent)																
0–30° knee angle	9 ± 5	19 ± 11	15 ± 8	22 ± 8	28 ± 22	34 ± 21	25 ± 19	12 ± 8	15 ± 9	25 ± 13	24 ± 12	24 ± 11	4 ± 2	19 ± 12	38 ± 19	37 ± 14
31–60° knee angle	11 ± 4	31 ± 8	29 ± 13	17 ± 9	21 ± 13	34 ± 17	18 ± 13	16 ± 8	19 ± 9	31 ± 13	28 ± 12	29 ± 11	7 ± 4	25 ± 12	57 ± 16	61 ± 22
61–90° knee angle	20 ± 9	37 ± 10	33 ± 11	9 ± 4	9 ± 9	13 ± 8	7 ± 3	31 ± 17	40 ± 27	59 ± 44	47 ± 25	51 ± 25	5 ± 3	14 ± 7	35 ± 15	36 ± 16
Pairwise comparisons in	a,c	a, b, c	b,c	a, c	a, c	a	a						b, c	a, c	a	
knee angle intervals	e,f	d,f	d,f	e,f	f	e,f	e,f	e,f	e,f	e,f	e,f	e,f			d,e	d,e
	g,h,i	g,h,i	g,h,i	g,h,i	g,h,i	g,h	g,h	g	g	g	g	g	g,h,i	- g,h,i	g,h,i	g,h,i

* Significant difference ($P < 0.01$) between sumo and convention deadlifts.
** Significant differences ($P < 0.01$) between belt and no-belt.
Pairwise Comparisons ($p<0.01$) in Knee Angle Intervals
Knee Extending Interval Comparisons (a-c): a) 90-61° vs. 60-31°; b) 60-31° vs. 30-0°; c) 90-61° vs. 30-0°
Knee Flexing Interval Comparisons (d-f): d) 0-30° vs. 31-60°; e) 31-60° vs. 61-90°; f) 0-30° vs. 61-90°
Knee Extending versus Knee Flexing Interals Comparisons (g-i): g) 90-61° vs. 61-90°; h) 60-31° vs. 31-60°; i) 30-0° vs. 0-30°

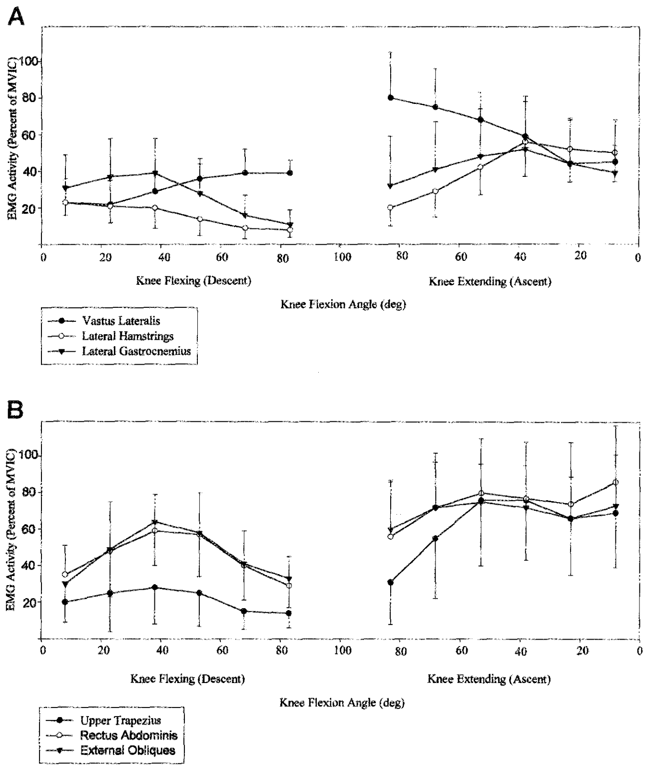

FIGURE 1—Mean and SD of EMG activity for select muscles during the deadlift (collapsed across sumo and conventional deadlift styles and belt and no-belt comparisons).

flexion moments exclusively throughout the lift, whereas the conventional deadlift generated plantar flexor moments exclusively throughout the lift. These kinetic results are consistent with our EMG findings between sumo and conventional deadlifts, in which ankle dorsiflexion activity from the tibialis anterior were greater in the sumo deadlift and ankle plantar flexor activity from the medial gastrocnemius was greater in the conventional deadlift. It can be inferred from these data that the sumo deadlift may be more effective overall in recruiting the ankle dorsiflexors, whereas the conventional deadlift may be more effective overall in recruiting the ankle plantar flexors. However, it should be emphasized that the percent differences in tibialis anterior and medial gastrocnemius activity between sumo and conventional deadlifts were relatively small.

Escamilla et al. (6,7) reported significantly greater knee extensor moments during the sumo deadlift compared to the conventional deadlift during a 3-D analysis of the deadlift. These kinetic results are consistent with our EMG findings. The significantly greater vasti activity in the sumo deadlift compared to the conventional deadlift support our original hypothesis that knee extensor activity would be greater in the sumo deadlift. It can be inferred from these data that the sumo deadlift may be more effective than the conventional deadlift in recruiting the vasti muscles. In contrast, no significant knee moments were found by Cholewicki et al. (2) between sumo and conventional deadlifts. However, the knee moments reported by Cholewicki et al. (2) were calculated from a two dimensional (2-D) sagittal plane analysis. Although a 2-D analysis has been shown to be adequate for the conventional deadlift (6), significant differences in knee moments and moment arms have been demonstrated in the sumo deadlift between 2-D and 3-D analyses (6,7). Because in the sumo deadlift the knees move out of a sagittal plane and into a frontal plane as the stance widens and the feet turn out, a 2-D analysis will produce erroneous knee moments and moment arms. The 65 ± 17 cm stance width and 25 ± 9° mid-foot abduction during the sumo deadlift are similar but slightly less than the 70 ± 11 cm stance width and 42 ± 8° mid-foot abduction previously reported by Escamilla et al. (6).

No significant differences in hip extensor moments have been previously reported between sumo and conventional deadlifts (2,6). These data are consistent with our EMG findings, in which there were generally no significant differences in lateral hamstring, medial hamstring, and gluteus maximus activity between sumo and conventional deadlifts.

Cholewicki et al. (2) conducted the only known study that compared back extensor moments between sumo and conventional deadlifts. These authors reported a significantly greater L4/L5 back extensor moment in the conventional deadlift compared with the sumo deadlift. Our EMG data do not support these findings, because no significant differences were found in L3 and T12 paraspinal activity during the ascent, which implies that the sumo deadlift may be as effective as the conventional deadlift in recruiting the paraspinal muscles.

Tibialis anterior, hip adductor, gluteus maximus, and L3 and T12 paraspinal activity were significantly greater during the final 30° of the descent (i.e., 61–90°KA) compared with the other knee angle intervals. These muscles may fire more toward the end of the descent to enhance stability during this portion of the lift as the lifter decelerates the weight toward the end of the lift.

High lumbar compressive and shear forces have been reported during the deadlift (2,8). These compressive and shear forces can be decreased by wearing a weight-training belt (14). A tightly worn weight-belt can help to pressurize the abdominal cavity, enabling it to bear up to 50% of the load normally placed on the spinal column and associated structures (12). Several lifting studies have shown an increase in IAP from 13 to 40% when a weight-belt was used (9,13,14,16), thus unloading the spine and decreasing shear and compressive forces. Employing a lifting belt can also affect muscle activity (Table 1). In the current study, the rectus abdominis and external obliques were the only muscles affected by wearing a belt during the deadlift. The greater external oblique activity in the belt condition compared to the no-belt condition is in agreement with data from Lander et al. (14) during the barbell squat, which is performed in a similar manner as the barbell deadlift. Greater external oblique activity without wearing a belt may be needed to enhance trunk stabilization and rigidity, which normally is enhanced by the belt due to increased IAP (14). Although increased IAP generates a force that resists spinal flexion, thus unloading the spine and decreasing paraspinal activity, we did not find a significant difference in paraspinal activity between the two belt conditions. The greater rectus abdominis activity with a belt compared to without a belt is in agreement with lifting data from Miyamoto et al. (19). The greater rectus abdominis activity with the belt may occur because the belt works as a resistance against the contraction of the rectus abdominis, thus allowing a more intense voluntary contraction than without a belt (19).

The magnitudes and patterns of quadriceps activity in the current study have also been observed during the barbell squat (4,5,27–29). Both the vastus medialis and vastus lateralis produced approximately the same amount of activity, which is in agreement with vasti data from several squat studies (4,5,18,24,27). The lower activity observed in the rectus femoris compared to the vasti muscles may be due to its biarticular function as both a hip flexor and knee extensor. Increased activity from the rectus femoris would increase hip flexor torque, with a concomitant increase in the amount of hip extensor torque needed from the hamstrings, gluteus maximus, and adductor magnus (ischial fibers) to extend the hip. Employing the same 12 RM lifting intensity as the current study, Escamilla et al. (4) and Wilk et al. (27) reported similar peak hamstring activity (30–80% of a MVIC) during the squat as observed in the current study. In addition, numerous squat studies (4,10,20,26,27) have reported that peak hamstring activity occurs between 10 and 60°KA, which is in agreement with our hamstring data, which were highest between 0 and 60°KA.

The significantly greater medial gastrocnemius activity with the more narrow stance conventional deadlift compared with the wider stance sumo deadlift is in agreement with data from Escamilla et al. (5), who reported significantly greater gastrocnemius activity during the narrow stance squat compared to the wide stance squat. In addition, both Escamilla et al. (5) and McCaw and Melrose (15) reported no significant differences in rectus femoris and hamstring activity between narrow and wide stance squats, which are similar to the results found between the conventional and sumo deadlifts. In contrast, although vasti activity has not been shown to be different between narrow and wide stance squats (5,15), the wider stance sumo deadlift did show greater vasti activity than the more narrow stance conventional deadlift. Interestingly, the 29-cm narrow stance width and 57-cm wide stance width reported by Escamilla et al. (5) during the squat are very similar to the 33-cm stance width for the conventional deadlift and 65-cm stance width for the sumo deadlift. It can be inferred from these data that gastrocnemius recruitment may be more effective with a narrow lifting stance, whereas performing the deadlift with a wider stance may be more effective in vasti recruitment. These results may have clinical implications, because vasti activity is very important in knee rehabilitation programs, especially the vastus medialis. Moreover, because the deadlift is considered a closed kinetic chain exercise (22), it may be appropriate during knee rehabilitation, such as after ACL reconstruction. This is especially true for strength athletes (e.g., American football players) who already employ the deadlift in their training regimen. Closed chain exercises, like the squat and deadlift, elicit moderate to high co-contraction from knee musculature (quadriceps, hamstrings, and gastrocnemius) and have been shown to minimize ACL strain (21,23,26,31). Because the deadlift is performed in a similar manner as the squat, the deadlift may provide similar benefits during ACL rehabilitation. Additional studies are needed to test this hypothesis. Moderate to high hamstring activity has been reported during the conventional straight leg deadlift (30), which may help protect the ACL during knee rehabilitation.

CONCLUSION

From our EMG findings, the sumo deadlift may be more effective overall than the conventional deadlift in recruiting the vastus medialis, vastus lateralis, and tibialis anterior, whereas the conventional deadlift may be more effective overall than the sumo deadlift in recruiting the medial gastrocnemius. The primary effect of wearing a belt is that there was greater rectus abdominis activity and less external oblique activity. Therefore, wearing a belt during submaximal training does not appear to alter muscle activation patterns, except in abdominal musculature. Strength athletes may choose to employ either the sumo or convention deadlift depending on which muscles are considered most important to develop according to their training or rehabilitation protocols. Because the deadlift generated moderate to high co-contractions from the quadriceps, hamstrings, and gastrocnemius, it may be an effective closed kinetic chain exercise during knee rehabilitation, such as after ACL injury or reconstruction, although this hypothesis warrants further research. Also, because the joint moments that previously have been quantified during the deadlift were from a 1 RM deadlift, additional studies should be conducted comparing EMG between sumo and conventional deadlifts employing a 1 RM intensity.

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REFERENCES

1. Basmajian, J. V., and R. Blumenstein. *Electrode Placement in EMG Biofeedback.* Baltimore: Williams & Wilkins, 1980, pp. 79–86.
2. Cholewicki, J., S. M. Mcgill, and R. W. Norman. Lumbar spine loads during the lifting of extremely heavy weights. *Med. Sci. Sports Exerc.* 23:1179–1186, 1991.
3. Cram, J. R., and G. S. Kasman. *Introduction to Surface Electromyography.* Gaithersburg, MD: Aspen Publishers, 1998, pp. 273–374.
4. Escamilla, R. F., G. S. Fleisig, N. Zheng, S. W. Barrentine, K. E. Wilk, and J. R. Andrews. Biomechanics of the knee during closed kinetic chain and open kinetic chain exercises. *Med. Sci. Sports Exerc.* 30:556–569, 1998.
5. Escamilla, R. F., G. S. Fleisig, N. Zheng, et al. Effects of technique variations on knee biomechanics during the squat and leg press. *Med Sci Sports Exerc.* 33:1552–1266, 2001.
6. Escamilla, R. F., A. C. Francisco, G. S. Fleisig, et al. A three-dimensional biomechanical analysis of sumo and conventional style deadlifts. *Med. Sci. Sports Exerc.* 32:1265–1275, 2000.
7. Escamilla, R. F., T. M. Lowry, D. C. Osbahr, and K. W. Speer. Biomechanical analysis of the deadlift during the 1999 Special Olympics World Games. *Med. Sci. Sports Exerc.* 33:1345–1353, 2001.
8. Granhed, H., R. Jonson, and T. Hansson. The loads on the lumbar spine during extreme weight lifting. *Spine* 12:146–149, 1987.
9. Harman, E. A., R. M. Rosenstein, P. N. Frykman, and G. A. Nigro. Effects of a belt on intra-abdominal pressure during weight lifting. *Med. Sci. Sports Exerc.* 21:186–190, 1989.
10. Isear, J. A., Jr., J. C. Erickson, and T. W. Worrell. EMG analysis of lower extremity muscle recruitment patterns during an unloaded squat. *Med. Sci. Sports Exerc.* 29:532–539, 1997.
11. Kendall, F. P., E. K. Mccreary, and P. G. Provance. *Muscles, Testing and Function.* Baltimore: Williams & Wilkins, 1993, pp. 70–319.
12. Lander, J. E., B. T. Bates, and P. Devita. Biomechanics of the squat exercise using a modified center of mass bar. *Med. Sci. Sports Exerc.* 18:469–478, 1986.
13. Lander, J. E., J. R. Hundley, and R. L. Simonton. The effectiveness of weight-belts during multiple repetitions of the squat exercise. *Med. Sci. Sports Exerc.* 24:603–609, 1992.
14. Lander, J. E., R. L. Simonton, and J. K. Giacobbe. The effectiveness of weight-belts during the squat exercise. *Med. Sci. Sports Exerc.* 22:117–126, 1990.
15. Mccaw, S. T., and D. R. Melrose. Stance width and bar load effects on leg muscle activity during the parallel squat. *Med. Sci. Sports Exerc.* 31:428–436, 1999.
16. Mcgill, S. M., R. W. Norman, and M. T. Sharratt. The effect of an abdominal belt on trunk muscle activity and intra-abdominal pressure during squat lifts. *Ergonomics.* 33:147–160, 1990.
17. Mcguigan, M. R. M., and B. D. Wilson. Biomechanical analysis of the deadlift. *J. Strength Condit. Res.* 10:250–255, 1996.
18. Mirzabeigi, E., C. Jordan, J. K. Gronley, N. L. Rockowitz, and J. Perry. Isolation of the vastus medialis oblique muscle during exercise. *Am. J. Sports Med.* 27:50–53, 1999.
19. Miyamoto, K., N. Iinuma, M. Maeda, E. Wada, and K. Shimizu. Effects of abdominal belts on intra-abdominal pressure, intra-muscular pressure in the erector spinae muscles and myoelectrical activities of trunk muscles. *Clin. Biomech.* 14:79–87, 1999.
20. Ninos, J. C., J. J. Irrgang, R. Burdett, and J. R. Weiss. Electromyographic analysis of the squat performed in self-selected lower extremity neutral rotation and 30 degrees of lower extremity turn-out from the self-selected neutral position. *J. Orthop. Sports Phys. Ther.* 25:307–315, 1997.
21. Ohkoshi, Y., K. Yasuda, K. Kaneda, T. Wada, and M. Yamanaka. Biomechanical analysis of rehabilitation in the standing position. *Am. J. Sports Med.* 19:605–611, 1991.
22. Palmitier, R. A., K. N. An, S. G. Scott, and E. Y. Chao. Kinetic chain exercise in knee rehabilitation. *Sports Med.* 11:402–413, 1991.
23. Shelbourn, K. D., and P. Nitz. Accelerated rehabilitation after anterior cruciate ligament reconstruction. *Am. J. Sports Med.* 18: 292–299, 1990.
24. Signorile, J. F., B. Weber, B. Roll, J. F. Caruso, I. Lowensteyn, and A. C. Perry. An electromyographical comparison of the squat and knee extension exercises. *J. Strength Condit. Res.* 8:178–183, 1994.
25. Stone, M. H., H. O'Bryant, and J. Garhammer. A hypothetical model for strength training. *J. Sports Med. Phys. Fitness.* 21:342–351, 1981.
26. Stuart, M. J., D. A. Meglan, G. E. Lutz, E. S. Growney, and K. N. An. Comparison of intersegmental tibiofemoral joint forces and muscle activity during various closed kinetic chain exercises. *Am. J. Sports Med.* 24:792–799, 1996.
27. Wilk, K. E., R. F. Escamilla, G. S. Fleisig, S. W. Barrentine, J. R. Andrews, and M. L. Boyd. A comparison of tibiofemoral joint forces and electromyographic activity during open and

closed kinetic chain exercises. *Am. J. Sports Med.* 24:518–527, 1996.

28. Wretenberg, P., Y. Feng, and U. P. Arborelius. High-and low-bar squatting techniques during weight-training. *Med. Sci. Sports Exerc.* 28:218–224, 1996.
29. Wretenberg, P., Y. Feng, F. Lindberg, and U. P. Arborelius. Joint moments of force and quadriceps activity during squatting exercise. *Scand J. Med. Sci. Sports.* 3:244–250, 1993.
30. Wright, G. A., T. H. Delong, and G. Gehlsen. Electromyographic activity of the hamstrings during performance of the leg curl, stiff-leg deadlift, and back squat movements. *J. Strength Condit. Res.* 13:168–174, 1999.
31. Yack, H. J., C. E. Collins, and T. J. Whieldon. Comparison of closed and open kinetic chain exercise in the anterior cruciate ligament-deficient knee. *Am. J. Sports Med.* 21:49–54, 1993.