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A kinematic, kinetic and electromyographic analysis of 1-repetition maximum deadlifts

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Abstract

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Summary : To date, no study has explored the deadlift in terms of studying both individual body joint angles and muscle recruitment strategy on well-trained powerlifters lifting at 1-repetition maximum (1RM). The primary purpose of this study was to describe these two technical parameters and the relationship between them during 1RM deadlifts. The secondary purpose was to investigate the correlations between the relative strength parameter (1RM/BW) and lifting angle and muscle activation parameters. Ten male powerlifters with >1 year of training experience with the deadlift volunteered to participate in the study. Their mean (±SD) age, body mass, height, 1RM and 1RM normalized for body mass were 25±3 years, 86±4 kg, 183±7 cm, 220±26 kg and 2,6±0,2 1RM/body mass, respectively. The subjects were equipped with six EMG transmitters and 25 reflective markers and performed 1RM deadlifts, with each lift recorded by 16 motion analysis cameras. Main findings were considered as 1) hunching of the lower back occurred probably as a result of insufficient erector spinae (ES) activation, 2) a mean supramaximal (>100% of maximal voluntary isometric contraction (MVIC)) activation of the biceps femoris (BF) and the gluteus maximus (GM) at knee passage (KP), 3) a "shift" in dominating knee muscle activity from the vastus medialis at lift-off (LO), to BF at KP. Furthermore, Pearson's *r* correlation analyses revealed significant ($p <.05$), strong correlations between 1RM/body mass and 1) BW (-*r*=.75), 2) GM activity at LO (*r*=.63) and 3) hip angle (HA) at LO (*r*=.64). These might act as important findings, from a performance perspective as well as from a sports injury profilactic point of view.

Sammanfattning: Ingen studie har ännu undersökt maximala marklyft på vältränade styrkelyftare genom ledvinklar såväl som muskelrekryteringsstrategier. Det primära syftet med denna studie var att redogöra för dessa två tekniska parametrar och förhållandet mellan dem under maximala (1RM) marklyft. Det sekundära syftet med denna studie var att undersöka korrelationer mellan relativ styrka (1RM/kroppsvikt), och ledvinkel- och muskelaktiveringsparametrar. Tio manliga styrkelyftare med >1 års träningserfarenhet av marklyftsträning deltog. Deras genomsnittliga (±SA) ålder, kroppsvikt (BW), längd, 1RM och 1RM/BW var 25±3 år, 86±4 kg, 183±7 cm, 220±26 kg och 2,6±0,2 1RM/BW. Försökspersonerna utrustades med sex stycken EMG-transmittorer samt 25 stycken reflexmarkörer och utförde marklyft på en intensitet motsvarande 1RM, där varje lyft spelades in av 16 stycken rörelseanalyskameror. De huvudsakliga fynden i studien löd enligt följande: 1) krummande av ländryggen uppkom sannolikt som ett resultat av bristfällig aktivitet i erector spinae (ES), 2) en genomsnittlig supramaximal (>100% av maximal isometrisk kontraktion (MVIC)) aktivering av biceps femoris (BF) samt gluteus maximus (GM) vid knäpassage (KP), 3) en "växling" i dominerande knämuskelaktivitet från vastus medialis (VM) vid dragläge (LO), till BF vid KP. Vidare visade Pearsons *r*-korrelationsanalyser signifikanta ($p < .05$) och starka korrelationsvärden mellan 1RM/BW och 1) BW(-*r*=.75), 2) GM-aktivitet vid LO (*r*=.63) och 3) höftvinkel (HA) vid LO (*r*=.64). Dessa fynd kan betraktas som betydelsefulla från ett prestationsperspektiv såväl som från ett skadeprofylaktiskt sådant.

Register

Foreword

The authors of this study would like to express special thanks to Patrik Almström and Frida Bakkman from Qualisys AB, Gothenburg, tutor Jesper Augustsson as well as Tobias Hein, Stefan Grau, Roy Tranberg and Ruoli Wang for conducting us through the process of completing this study. Also, we would like to thank the lifters for their participation in the study.

Introduction

The fact that physical activity is healthy seems to be well-known (Wilmore & Knuttgen, 2003). Lots of people are physical active for health reasons, but some because they want to compete on an elite level in some kind of sport. Resistance training is well-used for people at all kinds of athletic levels. For example there are over two million people in Sweden who exercise this way, and thereby resistance training could be considered as the second largest physical activity next to walking (Riksidrottsförbundet, 2013). Barbell lifting is a common type of strength training, and powerlifting is one of the most popular variants to conduct this type of training on.

Powerlifting consists of three types of lifts with different embodiment. In the deadlift, the athlete is supposed to pull the bar off the floor until he or she is standing erect (International Powerlifting Federation, 2014). Recent research has explored this exercise from several different perspectives, such as deadlifting with or without the inclusion of chain resistance (Swinton, Stewart, Agouris, Keogh & Lloyd, 2011), the difference between conventional and Trap Bar deadlifts (Swinton, Stewart, Agouris, Keogh & Lloyd, 2011) as well as between conventional as sumo deadlifts (Escamilla, Fransisco, Fleisig, Barrentine, Welch, Kayes, Speer & Andrews, 2000; Escamilla, Fransisco, Kayes, Speer & Moorman CT 3rd, 2002; McGuigan & Wilson, 1996) and muscle force and activation when deadlifting on stable and unstable surfaces (Chulvi-Medrano, García-Masso, Colado, Pablos, de Moraes & Fuster, 2010).

Since the deadlift is a complex and multi-joint exercise, it could be assumed that there are different ways of executing and completing the exercise.

For instance, Davis, Troup and Bernard (1965) was one of the first studies to report that the applied lifting technique may vary depending on the load being lifted. More specifically, they noted that the hips tended to rise faster than the shoulders, along with the trunk adopting a more stooping posture, when attempting to lift relatively heavy weights with knees in an initially bent position.

Analyzing lifts by a population consisting of competing powerlifters, Brown and Abani (1985) reached a similar conclusion, i.e. a dominance in knee extension over hip extension occurs during the early stage of the deadlift. Utilizing a more modern data collection apparatus, yet still competing powerlifters, Hales, Johnson and Johnson (2009) confirmed that the deadlift is a sequential (segmented) rather than a simultaneous (synergistic) movement. This suggests that the deadlift demonstrates a unique movement pattern, and therefore, it is likely that specific muscular strategies transpire during the execution of the exercise.

Escamilla, Fransisco, Kayes, Speer and Moorman CT 3rd (2002) investigated the muscle recruitment pattern in conventional deadlifts through an extensive electromyographic exploration. However, this study was based on the analysis of subjects lifting a load equivalent to their 12RM (corresponding to approximately 70-75% 1RM). Since Swinton, Stewart, Agouris, Keogh and Lloyd (2011) showed that this load may not be heavy enough to induce significant technical disturbances - for example considerable lumbar flexion or altered hip angle throughout the lift – there could be reason to believe that the muscle recruitment pattern displayed by Escamilla is not applicable to maximum load deadlifts.

To date, no study has explored the deadlift in terms of studying both individual angles and muscle recruitment strategies on well-trained powerlifters lifting at 1RM. Therefore, the primary purpose of this study was to describe these two technical parameters and the relationship between them under the extreme conditions that a maximum deadlift represents.

Furthermore, there are indications that technical variances exist between deadlifters situated at different strength levels. For example, Brown and Abani (1985) reported that skilled lifters tended to position their shanks and thighs significantly closer to vertical at the time of lift-off, compared with unskilled lifters. The effect on muscle activation of such variations in individual pulling techniques is not known. Thus, the secondary purpose of this study was to investigate the correlations between the relative strength parameter (1RM/BW) and lifting angle and muscle activation parameters.

Methods

Subjects

Ten resistance-trained men participated in the study (age: 25,4 (SD 3,07) years; stature: 183,1 (SD 6,64) cm; mass: 86,13 (SD 3,70) kg; self-reported deadlift 1RM: 220,5 (SD 25,86) kg; deadlift 1RM/mass: 2,57 (SD 0,24)). Subjects were included based on the criteria that 1) they had been training the deadlift regularly for at least one year, 2) they possessed a relative deadlift strength level equivalent to or above 1RM = 2,25 x BW-1. Female lifters were excluded with the aim of obtaining a homogenous group of studied subjets. All subjects were informed about the potential risks involved prior to the study in writing (Appendix 2).

Data Collection

All subjects completed their trials seperately from one another. The test protocol began with a mandatory body height measurement after which participants performed a 5 minute general warm-up on a stationary bike (Monark, Sweden). Subjects then stripped down to cycling shorts in order to enable the subsequent EMG and reflective marker placement. Twelve disposable surface electrodes (Blue Sensor N, N-00-S, Ambu A/S, Ballerup, Denmark) were attached with double-sided adhesive tape in pairs on the following six muscle groups: 1) Vastus Medialis (VM), 2) Biceps Femoris (BF), 3) Gluteus Maximus (GM), 4) Erector Spinae (ES) (at the level of T12), 5) Trapezius (T) (at the level of T3) and 6) Soleus (S). Six portable EMG transmitters (Noraxon U.S.A. Inc., Scottsdale, AZ) were connected to each of the surface electrode pair, and attached to the skin approximately 3 cm from the electrodes. The procedure of placing EMG sensors and transmitters, including skin preparation, was standardized as specified by Konrad (2005). Subjects then performed maximum voluntary isometric contractions (MVIC), one per muscle group, in fixated body postions recommended by Konrad (2005). The MVICs were carried out on a vaulting box in order to facilitate the switch between different MVIC positions.

Following the completion of the MVICs, a total of 25 reflective markers (19 mm in diameter; Qualisys AB, Gothenburg, Sweden), were attached to the following landmarks using double-sided adhesive tape: 1) spinous process of the 1st thoracic vertebra, 2) spinous process of the 7th thoracic vertebra, 3) spinous process of the 12th thoracic vertebra, 4) sacrum, midway between the posterior superior iliac spines, 5) superior border of the manubrium, 6) left and right acromion processes, 7) left and right anterior superior iliac spine, 8) left and right greater trochanter, 9) 2cm superior of the borders of the left and right patella, 10) left and right tibial tuberosity, 11) left and right lateral knee joint line, 12) left and right medial knee joint line 13) left and right lateral malleolus, 14) between the heads of the 1st and the 2nd metatarsus and 15) posterior part of the calcaneus. Additionally, two larger reflective markers (30 mm in diameter; Qualisys AB, Gothenburg, Sweden) were placed on either ends of a 20kg powerlifting barbell (powerlifting competition bar, Eleiko, Halmstad, Sweden). The placement of both EMG sensors and transmitters as well as the reflective markers was carried out by the same test leader on all subjects, with the purpose of decreasing interrater reliability (Baechle & Earle, 2008).

Succeeding the MVICs, subjects were instructed to warm up in the deadlift, lifting one to ten repetitions at progressive submaximal and optional weights, with the goal of ultimately achieving a daily 1RM. Because of the subjects and the test leaders previous experience with 1RM attempts in the deadlift, all subjects could accurately predict their daily 1RM based on the warm-up. Initial warm-up sets were performed outside the recording area and with optional rest. When subjects began reaching approximately 80% of their predicted 1RM, the barbell was placed directly over and with the weight plates (olympic weightlifting competition discs, Eleiko, Halmstad, Sweden) on either side of two adjacent piezoelectric force plates (900x600x100 mm, Type 9287CA Kistler Nordic AB, Mölndal, Sweden). Subjetcs then performed 1RM attempts, increasing the weight each time a successful attempt was made until failure was attained or an obvious 1RM had been accomplished. An attempt was considered successful when a participant was standing in an erect posture holding the barbell with shoulders, knees, hips and back completely locked out. Trials were performed with one foot on each of the two force platforms, in a recording area covered by a total of 16 motion analysis cameras (Qualisys AB, Gothenburg, Sweden). After the completed deadlift attempts, the bodyweight of each participant was registered using one of the force platforms. Marker position and ground reaction force data were captured at 500 and 1,000 Hz, respectively.

The data of the heaviest successfully made 1RM for each individual was stored for later analysis. A minimum of 4 minute rest was administered between each of the 1RM attempts, since this is the time of rest needed to ensure full recovery in full-body movements such as the deadlift (Williardson, 2006). All participants utilized a medum size weight lifting belt (Casall, Sweden) at all recorded attempts, and before each trial subjects covered their palms with chalk to avoid the case of failing an attempt because of slippery grip. Test leaders provided strong verbal encouragement during both the MVICs and the deadlifts, for the reason that this has been associated with increased peak force during maximum effort voluntary muscle action (McNair, Deplege, Brettkelly & Stanley, 1996).

Biomechanical Analyses

Biomechnical analyses were made using the software package Qualisys Track Manager (Version 2.7, Qualisys AB, Gothenburg, Sweden). Employing the three deadlift phases identified by Hales, Johnson & Johnson (2009), knee, hip, and back angles were determined at two different occasions during each measured 1RM deadlift: 1) the commencement of the lift-off (LO) phase (the phase defined as when the barbell leaves the ground, proceeding until the barbell approaches the tibial tuberosity, approximately 6cm distal to the patella). The beginning of the LO phase was specified as the first frame where the barbell markers were raised above their initial resting position, and 2) when the barbell markers reached halfway through the knee passing (KP) phase. This occasion was specified as the first frame where the barbell reached the level of the patellae.

Angles were determined by using the following markers for the knee (A), hip (B), back 1 (C) och back 2 (D). A) left and right lateral malleolus, left and right lateral knee joint line and left and right greater trochanter, B) left and right lateral knee joint line, left and right greater trochanter and left and right acromion processes, C) sacrum (midway between the posterior superior iliac spines), spinous process of the 12th thoracic vertebra and spinous process of the 7th thoracic vertebra and D) spinous process of the 12th thoracic vertebra, spinous process of the 7th thoracic vertebra and spinous process of the 1st thoracic vertebra. When two bilateral markers were utilized for angle determination, calculations were made based on the mean value of the two markers.

EMG values expressed relative to MVICs for the six muscle groups were established during the two mentioned lift occasions. Rectification, smoothing (300ms) and amplitude normalization of the EMG data were made (MyoReasearch XP, Noraxon, Scottsdale, AZ, USA) based on the recommendations by Konrad (2005).

Statistical Analyses

Correlation analyses for the six muscle groups, knee, hip and back angles as well as BW, 1RM/BW and 1RM were executed, equivalent to 253 separate analyses. Statistical computations were carried out using the software package SPSS (Version 19.0, SPSS Inc., Chicago, IL, USA). Interpreting the correlation analyses, statements by Portney and Watkins (2000) were utilized. Effect size calculations were carried out for parameters possibly differing on a group level, using the formula stated by Cohen (1988) and in due course by Rhea (2004).

Results

Mean 1RM deadlift for the participants was 210,6 (SD 14,20) kg. 1RM/BW was 2,46 (SD 0,23). Knee, hip and back angles as well as EMG activity expressed relative to MVIC are shown below.

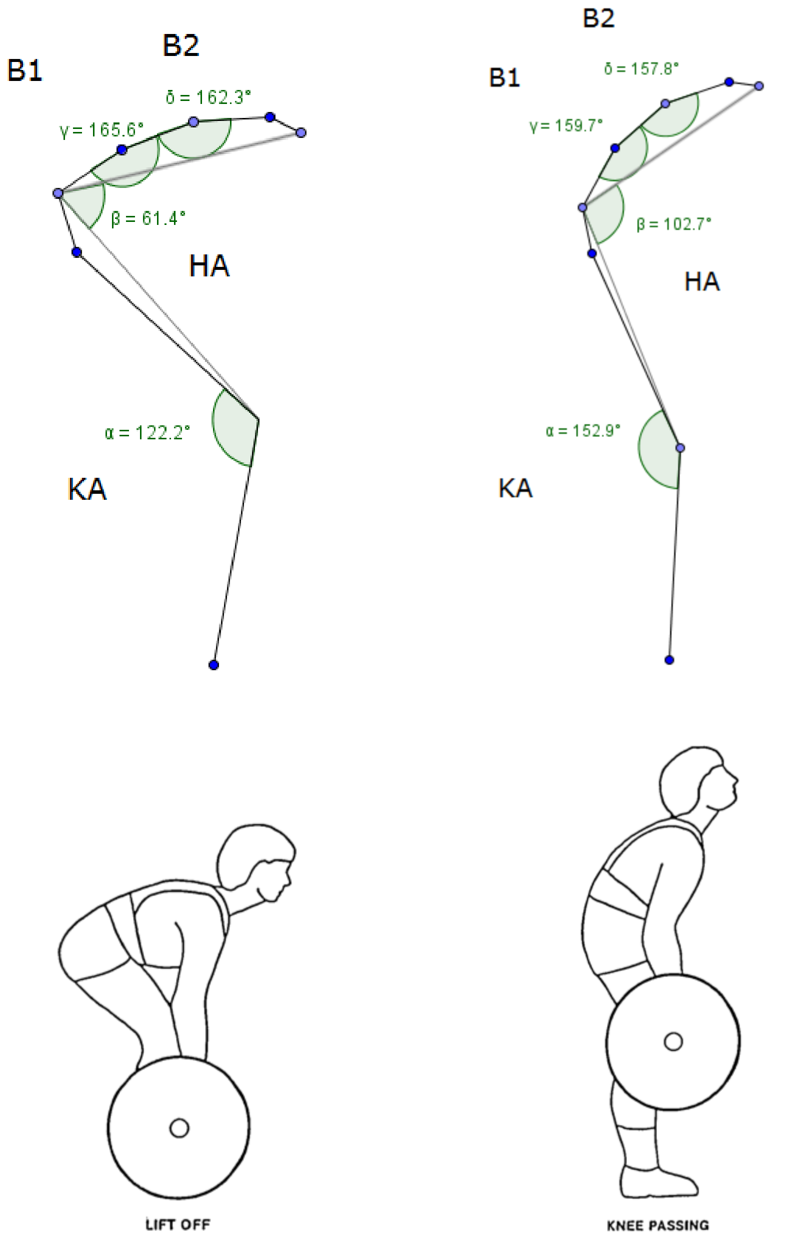

Figure 1 & 2 (top) and 3 & 4 (bottom). 1-2: Schematic stick-figure animations based on mean angles (knee (KA), hip (HA), lower back (B1) and upper back (B2)) at the time of LO (left) and KP (right). Angles are showed below in Table 1. 3-4: Drawing examples of LO and KP position (Brown & Abani, 1985).

Table 1. Knee, hip and back angles at the time of lift-off and knee passage

	Mean	Range	Minimum	Maximum	Std. Deviation
Lift-off					
Knee angle (°)	122,24	19,00	111,43	130,43	6,66
Hip angle (°)	61,43	12,23	54,13	66,36	3,87
Back angle 1 (°)	165,59	27,15	150,21	177,36	8,29
Back angle 2 (°)	162,27	16,50	151,98	168,48	5,75
Knee passage					
Knee angle (°)	152,89	14,60	148,57	163,17	4,73
Hip angle (°)	102,71	14,81	94,88	109,70	4,65
Back angle 1 (°)	159,73	18,41	148,93	167,34	6,12
Back angle 2 (°)	157,82	19,78	145,63	165,41	6,63

Table 2. EMG activity, expressed as percentage of MVIC at the time of lift-off and knee passage

	Mean	Range	Minimum	Maximum	Std. Deviation
Lift-off					
Vastus Medialis	94,94	57,93	73,33	131,26	17,35
Biceps Femoris	65,66	31,38	50,81	82,19	11,31
Gluteus Maximus	85,49	82,58	41,62	124,20	35,63
Erector Spinae	61,68	58,82	35,29	94,11	22,43
Trapezius	87,69	85,30	43,71	129,01	30,55
Soleus	74,04	63,21	44,20	107,41	12,61
Knee passage					
Vastus Medialis	40,83	40,21	19,31	59,52	13,71
Biceps Femoris	101,62	88,49	78,25	166,74	29,83
Gluteus Maximus	103,94	111,72	44,09	155,81	36,70
Erector Spinae	83,67	82,36	36,75	119,11	32,27
Trapezius	96,52	48,71	81,09	129,80	16,52
Soleus	68,41	62,08	43,12	105,2	20,14

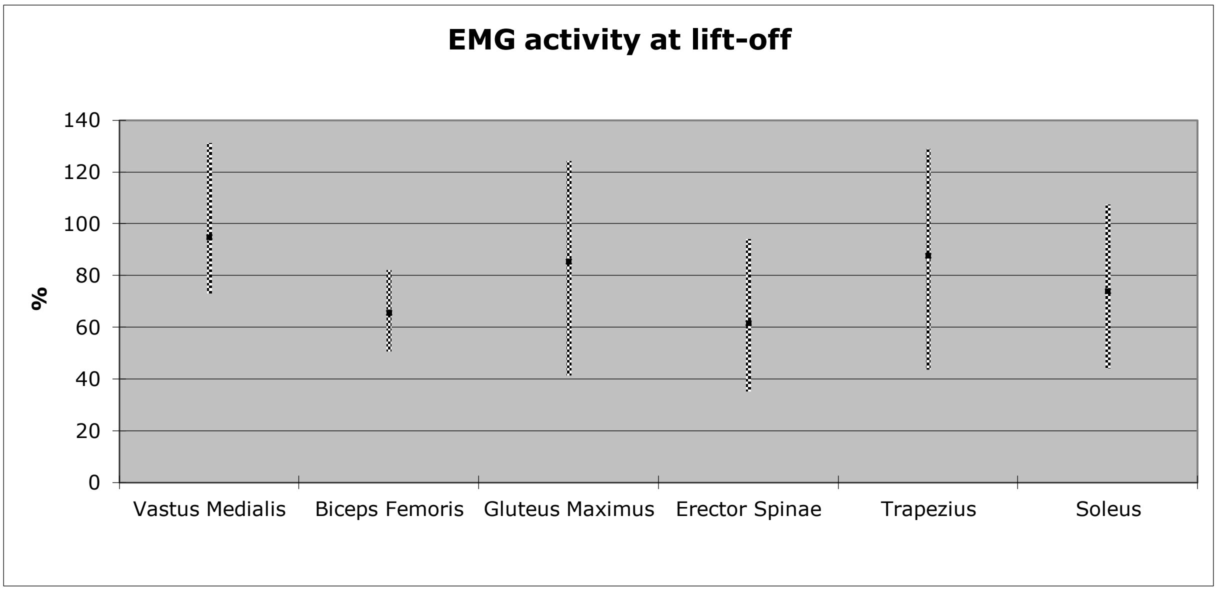

Figure 5. Mean EMG activity at lift-off. Values expressed as percentage of MVIC. Bars represent range (min-max).

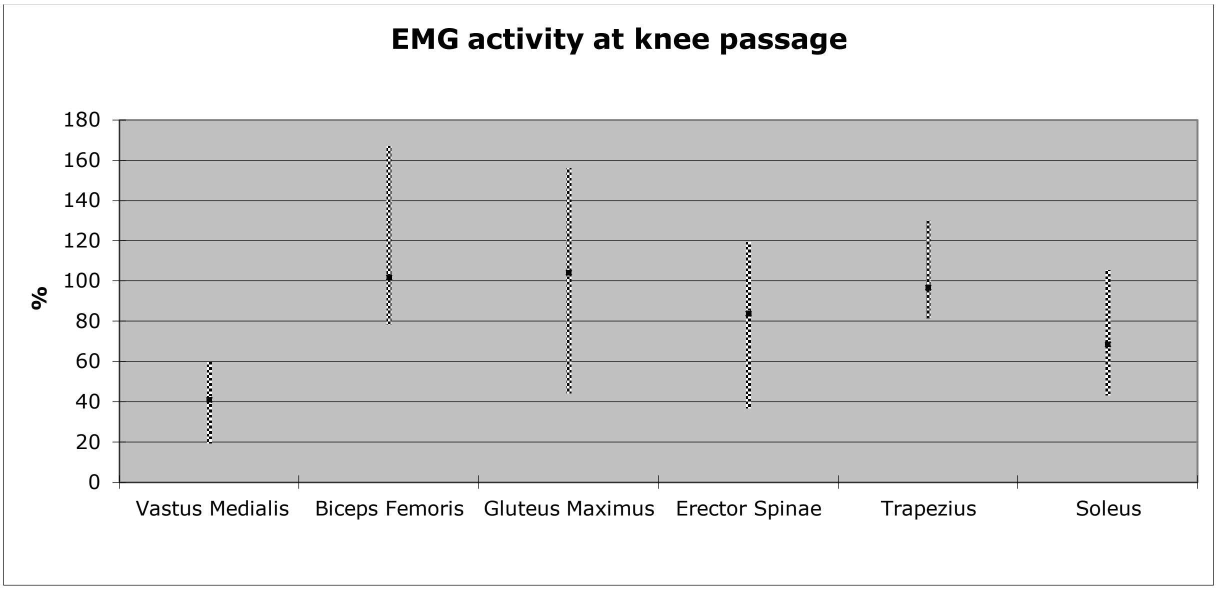

Figure 6. Mean EMG activity at knee passage. Values expressed as percentage of MVIC. Bars represent range (min-max).

Pearson correlation analysis showed significant and strong correlations ($p < .05$) between KA and GM activity at LO (.638; $R^2 = .407$); KA and GM activity at KP (.698, $R^2 = .487$); GM activity at LO and hip angle (HA) at KP (.762; $R^2 = .581$) and between KA and T activity at LO (.728; $R^2 = .530$).

Large effect sizes were detected for VM activity at LO and KP (-3,48, $p < .0001$), BF activity at LO and KP (1,75, $p < .001$) ES activity at LO and KP (.80, $p < .001$), BF activity and VM activity at LO (2,04, $p < .0001$) and for BF activity and VM activity at KP (2,79, $p < .0001$) (Figure 5-6).

Pearson correlation analyses also revealed significant ($p <.05$) and strong correlations between the relative strength parameter (1RM/BW) and 1) BW (-.75; $R^2 = .562$), 2) GM activity at LO (.63; $R^2 = .402$) and 3) HA at LO (.64; $R^2 = .406$). Additionally, non-significant trends between 1RM/BW and 1) KA at LO (.563; $p = .09$) and 2) HA at KP (.601; $p = ,066$) were observed.

Discussion

In the current study, the intention and primary purpose has been to describe the biomechanical circumstances by presenting body joint angles and muscle recruitment strategies. The results can be separated into a number of main findings.

1) The inability to maintain lumbar lordosis when lifting heavy weights have previously been described by Bejjani, Gross and Pugh (1984). When highly trained powerlifters performed 1RM deadlifts in this study, deviations from the so called neutral spine could be registered. This occurs in terms of flexion of the lower back (between the sacrum, the 12th and the 7th thoracic vertebrae) and the upper back (between the 12th, 7th and 1st thorcic vertebrae). From LO to KP, back angle 1 decreaces, meaning the lower back is hunched. Ascribing this to generally weak lumbar muscles seems unreasonably, since hunching of the lower back occurs concurrently as the mean ES activity amount to a mere 61,7% and 83,7% of MVIC at LO and KP, respectively. Accordingly, in this study ES has not been shown utilizing its full potential at LO nor KP during a maximal deadlift, which might be considered as unexpected, remarkable and paradoxical. Two possible explanations for why this is could be suggested:

a) Inability among the studied subjects to fully activate ES during the topical movement.

b) The ES activity is restricted as a part of a somatic compensation strategy. When the barbell has reached the knees, the body's hip extensors, mainly the GM and the BF, attempt to execute a hip extension, i.e erect the trunk, through very high activity (101,6% and 103,9% of MVIC, respectively). The demand for force development of these muscles during this part of the lift is, due to their dominating activity, presumably vast. However, when the weight is maximally heavy, the supramaximal activity of the GM and the BF will not be sufficient. In order to erect to trunk during the lift, the lifter is forced to hunch the lumbar and the thoracic spine, thereby shortening the lever arm between the barbell and the hip. Thus, the "assignment" of the ES is possibly to produce enough force to keep the torso tight, but without producing too much force, enabling the desired lever arm length between the barbell and the hip at the time of muscular sticking point for the GM and the BF. This way, the maximal muscular force that the hip extensors can produce is now sufficient and the 1RM lift can be completed. This reasoning is strengthened by the fact that an increase in ES activity can be registered at KP, possibly indicating the body’s effort to maintain the new and from a performance point of view more favourable lumbar angle once this has been attained. Although it remains unclear whether or not this observed movement pattern is conscious or unconscious, it might act as an explanation why slight lumbar flexion seems to be present during 1RM deadlifts in trained athletes.

2) The very large effect sizes (see the Results section) representing the change in activation of VM and BF at LO and KP respectively, might indicate that at LO, the quadriceps dominates over the hamstrings, and vice versa at KP. This is visually illustrated by the immense ”drop” in VM activity from LO to KP, and the corresponding rise in BF activity from LO to KP. Although measuring at a 12RM intensity, this muscle recruitment ”shifting” pattern from quadriceps dominance to hamstrings dominance when extending the knee during a deadlift could be observed in the study by Escamilla, *et al* (2002). This was according to the results, applicable not only to the VM and the lateral hamstrings (BF), but also the medial hamstrings, the rectus femoris and the vastus lateralis. This finding might provide a biomechanical foundation from which powerlifters can benefit. If a lifter determines his LO phase as the sticking point of the deadlift, incorporating imitating exercises that emphasizes the

quadriceps, may help her or him in overcoming such an obstacle. A similar approach might be applied regarding the hamstrings if sticking point occurs at KP.

3) The extensive recruitment of two of the main hip extensors, GM and BF, suggests that these muscles contribute greatly to the completion of a 1RM deadlift. Of the six analyzed muscle groups, GM and BF were the only muscles that reached a mean EMG value of more than 100% MVIC. This occured at KP, where, additionally the T reached a mean value of 97% MVIC, displaying that 1RM deadlifts stress the posterior chain to a very great degree.

Table 3. Knee angle comparisons between the current study and the existing litterature. Values expressed as mean (SD).

	Carbe and Lind, 2014	Escamilla *et al*, 2000	McGuigan and Wilson, 1996	Brown and Abani, 1985
1RM/BW	2,46	2,88	2,54	2,91
Knee (°), LO	122 (7)	124 (9)	120 (10)	123 (6)
Knee (°), KP	153 (5)	161 (8)	165 (*)	165 (6)

* Not statistically analyzed

These angle resemblances suggest that these is a possible ”standard range” regarding the knee angle at the starting position of a deadlift, to which experienced lifters subordinate. Hip angles are not included in the table on account of the differences between studies in defining the hip angle. Still, one of the conclusions in the comprehensive biomechanical analysis of 1RM deadlifts made by Brown and Abani (1985) was that skilled lifters (= obtaining a higher 1RM/BW value) assumed a more upright posture (greater HA) at lift-off compared to less skilled lifters. This finding could be statistically verified in the present study by the strong, positive correlation between HA at LO and the relative strength parameter. Whether the ability to adopt a more upright posture depends upon anthropometry (for example arm length) or technique (for example the ability to ”lengthen the arms” by protracting the scapulae and shoulders), or a combination of the two remains unclear, yet the current study, as well as previous literature, shows the importance of starting the deadlift with a greater HA in order to maximize deadlift performance.

The larger knee angles at KP found in other studies might be partly explained by the data collection methods used. In the three referred studies, live video camera recordings during competition was used to gather kinematic information. In Brown and Abani (1985), for example, the video camera was positioned perpendicular to the sagittal plane on the right side, possibly resulting in the lifting plates blocking body segments, resulting in less accurate data. Other possible explanations for greater knee angles at KP might be individual variations regarding lifting technique after LO, or greater relative strength demonstrated by the lifters in the referred studies.

Individual lifting technique

The muscle activity in GM seemed to differ a lot between the lifters in their respective 1RM attempts (SD 46,7% at LO and 47,6% at KP). This could of course be due to that the equipment's accuracy was inadequate, but another interesting theory is that the lifters have different approaches to how they use GM while lifting. Reasonably, the relatively experienced lifters in the study used their muscles to the best of their ability to force the weight up, and this strategy would possibly differ more or less in different parameters. The fact that the activity of GM, which seems to be a most essential muscle in the deadlift (85,5 % of MVIC at LO, a significant correlation with 1RM/BW and 103,9% of MVIC at KP), varies so much between the lifters, could indicate that this is an example of an important factor that is greatly influenced by the individual's technique.

Other muscles that proved to be especially interesting during the lift (thanks to the high level of activity during some part of the lift) are VM LO (94,9% of MVIC), T LO (87,7% of MVIC), T KP (96,5% of MVIC), BF KP (101,6% of MVIC) and ES KP (83,7% of MVIC).
It may seem most relevant to focus on the muscle groups that have the highest activity in the lift, although it obviously can be other factors that have significant importance. From what we can see in this study, is that ES at KP differs most between the individuals (SD 66,8%) and therefore, like GM, could be assumed as a factor that differs greatly depending on the individual lifting technique. T at KP, however, seems to be involved with considerably less span width among the lifters (SD 16.5%), and could thus be seen as an opposite example. What this means is that regardless of lifting technique, for trained lifters, the T at KP will be activated about the same.

Methodological issues

A main concern with the current study is the small sample size, resulting in relatively low statistical power for some of the calculations made. Regression analysis was avoided due to the small sample size. Thus because of this lack of statistical assurance, the findings and conclusions of this study should be interpret with caution and replicating studies with a larger sample size could be solicited.

Given that the lifts in the current study were measured in a laboratory environment, which differs from the lifters ordinary conditions and therefore could have influenced the subjects' performance, we think that the results are relatively similar compared with the lifters' quoted personal bests (1RM/BW at 2,46 compared to 2,54). We believe that such a high percent of the subjects' actual maximum, here considered as a daily maximum, is much more valuable for a 1RM analysis than what studies with lower weights could achieve.

We consider the EMG analysis method to be not entirely reliable, while for example some subjects felt that they had problems to activate some muscles to maximum in the MVIC measurement. Konrad (2005) also states that: "To describe the "typical" movement characteristics and neuromuscular input, investigators should consider not to analyze only one repetition but many of them (> 6 up to 30, depending on difficulty and fatigue factor) and average them to the "ensemble average" curve." Since this is impossible to conduct when measuring 1RM lifts, this forms a methodological issue regarding the EMG data collection.

A shortcoming of the study is that we used a marker model that couldn't measure the exact position of the joints. Our current model forced us to make approximations that probably differ slightly from an optimal model. However, an analysis of body motions based on optical markers is a much more reliable measurement than for example a video analysis (Tranberg, 2010).

Conclusions

In accordance with its primary purpose, this study has described body joint angles at critical times during a 1RM deadlift, as well as parts of the specific muscle recruitment pattern for six major muscles groups.

The main findings in this study were considered as

1) hunching of the lower back occurred probably as a result of insufficient ES activation, possibly indicating a compensatory somatic strategy,
2) a mean supramaximal (>100% MVIC) activation of the BF and the GM at KP,
3) a ”shift” in dominating knee muscle activity from the VM at LO, to BF at KP.

Furthermore, and reconnecting to the secondary purpose of the current study, Pearson's *r* correlation analyses revealed significant ($p < .05$), strong correlations between the relative strength parameter (1RM/body mass) and 1) BW (-*r*=.75), 2) GM activity at LO (*r*=.63) and 3) HA at LO (*r*=.64). These might act as important findings, from a performance perspective as well as from a sports injury prophylactic point of view. A suggestion for further research might be to investigate these findings more closely.

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Appendixes

1. Testschema

Förberedelser

1. Starta upp datorsystemet
2. Fixa in en cykel till testrummet
3. Rigga MVC
4. Kalibrera datorsystemet
5. Plocka fram stång och vikter + placera reflexmarkörer på stång
6. Klippa till fästtejp till markörer, plocka fram EMG-sensorer och reflexmarkörer
7. Plocka fram magnesium, stol att sitta på, vattenflaska, bälte, handduk, alsolsprit, rakhyvel, bomullstussar/papper

Testprocedur

1. Försöksperson introduceras kort till anläggningen och testproceduren
2. Försökspersonen byter om till shorts *och mäts*
3. Ev allmän uppvärmning om försökspersonen önskar (stationär cykel)
4. Försökspersonen sätter sig på golvet, EMG på Vastus Medialis & Soleus (inkl alkoholtvätt och ev rakning)
5. Försökspersonen sätter sig på en stol, EMG på Trapezius (inkl alkoholtvätt och ev rakning)
6. Försökspersonen lägger sig på golvet/en matta, EMG på Erector Spinae, Gluteus Maximus och Biceps Femoris
7. Försökspersonen sätter sig på plinten, MVC Vastus Medialis
8. Försökspersonen lägger sig på plinten, MVC Biceps Femoris, Gluteus Maximus, Erector Spinae, Trapezius
9. Försökspersonen ställer sig i utfallsposition på plinten, MVC Soleus
10. Försökspersonen ställer sig upp och tar på sig bälte (lätt åtdraget)
11. Samtliga reflexmarkörer placeras (inkl alkoholtvätt och ev rakning)
12. Test av statisk modell + *vägning*
13. Borttagning av ventrala knämarkörer
14. Test av dynamisk modell
15. Försökspersonen börjar värma upp i marklyft på valfri vikt (behöver inte ske på kraftplattorna)
16. Provmätningar på ett par submaximala uppvärmningslyft, kontroll av data
17. Huvudmätning (dagligt 1RM), kontroll av data
18. Ev ommätning om data är undermålig
19. Borttagning av markörer och EMG
20. Sparka ut försökspersonen

Övrig utrustning

- Vanlig tejp
- Handduk
- Lyftarbälte (för dem som inte har eget)
- Tidtagarur
- Skrivblock till testprotokollsnoteringar

2. Deltagarinfo

Information till deltagare i studien
"Marklyft – en biomekanisk analys"

Bakgrund
Ett 60-tal studier har studerat marklyft ur olika perspektiv, varav ett tiotal har gjort detta ur ett biomekaniskt sådant. Aspekter såsom draglägesvinklar och effektutveckling vid olika intensiteter har kartlagts, men ingen studie har undersökt lyftteknik – inkluderande både lyftvinklar och muskulär strategi och sambandet mellan dessa – under de extrema förhållanden som ett maximalt marklyft innebär.

Frågeställningar
Hur ser sambandet mellan muskulär strategi och lyftvinklar ut hos tränade marklyftare?
Hur skiljer sig individer gällande dessa två parametrar?

Syfte
Syftet är att bygga ut den biomekaniska kunskapsbank avseende marklyft som existerar inom litteraturen.

Projektets uppläggning
Testningen sker under ledning av två Sports Coachingstudenter som gör sitt examensarbete. Du som deltar i projektet kommer att utföra konventionella marklyft upp till ett dagligt 1RM.

Under testningen kommer vi att mäta 1) ground reaction force med hjälp av kraftplatta 2) lyftvinklar med hjälp av reflexmarkörer (placerade på 21 ställen på kroppen) och Qualisys Motion Capture Systems 3) muskelaktivering med hjälp av sex EMG-kanaler (Trapezius, Erector Spinae, Gluteus Maximus, Biceps Femoris, Vastus Medialis samt Soleus).

EMG-datainsamlingen innefattar Du utför ett antal maximala isometriska kontraktioner av de sex olika muskelgrupperna. Det registrerade marklyft kommer även att dokumenteras med digital videokamera som komplettering.

Du kommer att instrueras att lyfta med den teknik och det utförande Du normalt använder när Du utför övningen. Lyftarbälte kommer att användas.

Studien sker vid Idrottshögskolan, Göteborg.

Betydelse
Eftersom marklyft är en frekvent använd övning – både inom styrkelyft, men även som en del av den prestationsfrämjande styrketräningen andra idrotter använder sig av – finner vi det av stort intresse att utvidga kunskapen gällande övningen i fråga.

Vad innebär medverkan i projektet?
All testning är kostnadsfri. Eftersom reflexmarkörer och EMG-sensorer kommer att placeras över kroppen är det nödvändigt att testet genomförs i korta tajts. Dessa tillhandahålls av testledarna om personliga sådana inte medtages.

Du får genomföra fysisk träning dagarna innan testtillfället, men undvik att skaffa dig monstruös träningsvärk i relevanta muskelgrupper som omöjliggör att du kan leverera en rättvis bild av din prestationsförmåga.

När kommer du att deltaga?
Testtillfällen äger rum enligt en personligt överenskommen tidpunkt.

Lokal
Hus Idrottshögskolan, Skånegatan 14 B, Rum 214 (Biomekaniska Rummet).

Fördelar och risker med att deltaga i studien
Risker

Deltagandet i projektet kräver lite tid och uppoffring från din sida, och det krävs att du är tillgänglig den vid överenskomna tidpunkten för testtillfället. Marklyft är en tung övning och kan ge upphov till mindre allvarliga påföljder såsom träningsvärk, men kan vid olyckliga tillfällen även leda till både små och stora skador.

Fördelar

Du har möjlighet att deltaga i ett omfattande forskningsprojekt och kommer få kännedom om hur praktisk forskning går till. Alla som deltar i studien kommer vid projektets slut få resultatet av studien presenterat i form av ett exemplar av examensarbetet. Dessutom är man välkommen att lyssna på vår presentation av projektet.

Rätten att avbryta medverkan i projektet
Deltagandet i projektet är helt frivilligt och Du har ätt att när som helst avbryta Din medverkan utan att ange någon orsak.

Övrigt
Det är viktigt att reflexmarkörer och EMG-sensorer har nära kontakt med huden. Därför kommer alkoholtvättning och, om så krävs, eventuell rakning att genomföras. Magnesium tillhandahålls av testledningen.

Om Du undrar över något är Du välkommen att ringa någon av oss i projektgruppen

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