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REVIEW ARTICLE

Biomechanical and Neuromuscular Insights into Deadlift Variations: Implications for Sports Science, Strength Training, and Rehabilitation

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The deadlift is a fundamental exercise in resistance training, essential for the development of overall strength and power. This review synthesizes current research on kinematics and electromyographic (EMG) activity during deadlifts, highlighting the effects of different variations and techniques on performance and muscle activation. Kinematic studies have revealed significant differences in joint angles and movement patterns between conventional and sumo deadlifts, emphasizing the importance of technique and experience in optimizing performance and reducing injury risk. EMG analysis has also revealed distinct muscle activation profiles for key muscles, such as the vastus lateralis, gluteus maximus, and hamstrings, across different deadlift variations. These findings are critical for designing effective, individualized training programs in strength and conditioning, as well as developing targeted rehabilitation and injury prevention strategies in sports medicine. By understanding the biomechanical and neuromuscular dynamics of the deadlift, practitioners can improve performance, minimize injury risk, and tailor interventions to the specific needs of athletes. Thus, this review provides a comprehensive overview of the current understanding of deadlift kinematics and EMG activity, offering valuable insights for optimizing training and rehabilitation protocols.

Key words: Deadlift, Kinematics, Neuromuscular, Performance

INTRODUCTION

The deadlift is a foundational exercise in resistance training, widely recognized for its effectiveness in developing overall strength and power [1,2]. As one of the primary compound movements, it engages multiple muscle groups and joints, making it a key exercise in both athletic and general fitness programs [3]. The complexity of the deadlift, involving coordinated action across the lower body, trunk, and upper body, necessitates a detailed understanding of its biomechanical and neuromuscular components. Recent research has examined the kinematics and electromyographic (EMG) activity during deadlifts, providing insights into the influence of different variations and techniques on performance and muscle activation. This review aims to synthesize the current understanding of these aspects, highlighting the critical differences between deadlift variations and their implications for training.

The study of kinematics during the deadlift focuses on the movement patterns, joint angles, and velocities involved in executing the lift. Key findings indicate significant variations in joint angles and movement patterns between conventional and sumo deadlifts [4], as well as between skilled and unskilled lifters. These differences underscore the importance of technique and experience in optimizing performance and reducing injury risk. Similarly, EMG analysis has illuminated the muscle activation patterns associated with distinct deadlift variations, revealing distinctive activation profiles for muscles such as the vastus lateralis (VL), gluteus maximus (GM), and hamstrings. Understanding these patterns is crucial for the development of targeted training programs that aim to enhance specific muscle groups and achieve desired outcomes. This review will delve into these kinematic and EMG findings in detail, providing a comprehensive overview of the biomechanical and neuromuscular dynamics of deadlifting.

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CURRENT UNDERSTANDING OF KINEMATIC DURING DEADLIFT

Kinematics is the study of the motion of a body without consideration of the forces that cause it to move. Joint angles and velocities represent examples of kinematic variables. In resistance training, osteokinematics, which describes the movement of bones in relation to the three cardinal planes of motion (the sagittal, frontal, and transverse planes), is often examined. In particular, the joint angles during deadlifts are of significant interest. Relative joint angles pertain to the angular relationships between two body segments, whereas absolute joint angles refer to the angular relationship between a reference plane and a body segment. Moreover, the velocity characteristics of the body are also of critical importance in the field of kinematics. The velocity of the barbell during deadlifts is typically reported when contrasting different resistance training techniques. Furthermore, the vertical and horizontal displacements of the barbell during deadlifts are frequently documented.

It is often assumed that the barbell back squat and the deadlift have similar movement patterns and provide equivalent training results. Hales et al. [5] challenged these claims by analyzing the lower extremity kinematics during barbell back squats and deadlifts. They found different movement patterns and joint angles, indicating that barbell back squats involve simultaneous body movement, while deadlifts involve divided and sequential movement. This research reinforces that barbell back squats and deadlifts are distinctly different and suggests differing effects from each exercise.

Brown and Abani [6] reported that the angles of the shank and thigh were significantly closer to vertical in skilled lifters at lift-off timing. Furthermore, significantly greater knee and hip extension angles in skilled lifters were associated with the shank and thigh orientation at lift-off. The range of motion (ROM) was determined by subtracting the knee passing angle from the lift-off angle. This analysis revealed that the unskilled group exhibited greater ROM in the shank, thigh, and knee. The degree of movement in the head-neck segment was found to be significantly greater in skilled lifters, while the time taken to complete lift-off to knee passing was found to be greater in the unskilled group. Even in this relatively uncomplicated movement, differences in body segments were noted between the two groups.

McGuigan et al. [7] conducted a comparison between the conventional deadlift and the sumo deadlift using video analysis. The findings indicated that conventional deadlift users exhibited a significantly greater average knee extension range during barbell lift-off than sumo lift users. Additionally, the average ROM for various body segments and hip joints was notably larger in conventional deadlift users. Sumo lift users, on the other hand, were able to maintain a more upright position during lift initiation, evidenced by a significantly reduced trunk angle facilitated by a wider foot stance. The sumo deadlift's wide foot stance contributed to a reduced ROM for the barbell, minimizing the distance it had to travel from lift initiation to completion. Furthermore, keeping the barbell closer to the body in the sumo deadlift reduced stress on the lever arms. The ROM of the segment angles from lift-off to knee pass-over also showed significant differences. Conventional lift users had significantly less ROM in the tibia segment than sumo lift users. Additionally, conventional lift users exhibited a significantly larger ROM in the head-neck segment. The lift-off technique of the conventional deadlift, characterized by a more bent-over trunk posture, relied on the lower back muscles to generate the necessary trunk extension to complete the lift. Angle-angle diagrams illustrated that conventional lift users required a greater range of trunk extension as they approached a knee angle of 180 degrees. The study suggests that the sumo deadlift offers several biomechanical advantages over conventional deadlifts. Maintaining an upright posture reduces lumbar stress while effectively engaging trunk and lower limb muscle groups, making it an ideal training technique.

To mitigate the risk of injury during the deadlift, athletes are advised to maintain a close proximity of the bar to the body throughout the exercise [8]. A novel barbell design was introduced to enhance this principle to create a framework that allows athletes to position the load closer to their bodies. His innovation, designated as a trap bar with a trapezoidal shape, facilitates the alignment of the resistance's center of gravity with the body's center of gravity, in contrast to the standard barbell, where the center of gravity is positioned in front [9]. Subsequently, the trapezoidal shape was replaced with a hexagonal one, offering increased space and stability [10]. The hexagonal barbell has become a standard tool in resistance training for muscle strength and conditioning, often used to add variety to deadlift exercises [10]. Despite the widespread use of hexagonal barbells, there is a lack of published reports on the kinematics of deadlifts performed with this equipment. Understanding the differences in kinematics among deadlift variations is crucial for coaches and clinicians in exercise selection. Swinton et al. [11] conducted a study on professional powerlifters to compare the kinematics of the deadlift movement performed with a conventional deadlift and a hexagonal barbell deadlift. The participants performed one-repetition maximum

(1RM) tests with each deadlift and submaximal loads (10, 20, 30, 40, 50, 60, 70, 80%) of their 1RM. Joint angles were measured at intervals of 10% of the vertical displacement of the barbell. The only significant load results observed were for the ankle, indicating that maximum ankle plantarflexion was achieved after the concentric phase with increasing load.

A study was conducted to compare the average velocity-time curves of squats with and without the use of bands [12]. The findings indicated significantly higher velocity values during the initial 30% of the eccentric phase and the final 10% of the concentric phase when bands were used. However, these results do not conclusively demonstrate that training with banded squats is more effective for enhancing athletic performance than squatting without bands. Another investigation focused on the immediate effects of combining elastic bands and traditional free weights during deadlifts with moderate and heavy loads [13]. Twelve trained men participated, performing deadlifts at 60% and 85% of their 1RM under conditions with variable band resistance and traditional free weights. One workout had 15% band resistance and 85% free weight resistance, while the other had 35% band and 65% free weights. In general, the addition of bands resulted in an increase in velocity. Furthermore, a positive correlation was observed between the level of band resistance and the peak and relative power achieved during lifts at 85% of 1RM. The time required to reach maximal force, the interval between reaching maximal force and maximal power, and the interval between reaching maximal force and maximal velocity all decreased with increased elastic band resistance compared to traditional free weights at 60% of 1RM. These differences were significant only for traditional weightlifting and higher band resistance at 85% of 1RM during lifts. Consequently, practitioners may consider utilizing heavy bands during deadlifts with the intention of improving speed or power. Additionally, when using unstable loads, a study employed the Lyapunov exponent to assess bar movement stability during the bench press, while sample entropy tested the self-similarity of bar paths between conditions [14]. The results indicated that all unstable loads, with the exception of light bands and plate conditions, exhibited larger Lyapunov exponent values in the superior/inferior and mediolateral directions compared to stable loads. This suggests that lifters likely exert more effort to stabilize the bar in these directions when using unstable loads. Moreover, the sample entropy results demonstrated that bar movement is less predictable in the superior/inferior direction for all unstable loads than stable loads.

In barbell resistance training, the result of the body's movement acts on the barbell. In other words, the kinematic variables of the movement as a whole act on the barbell to change its three-dimensional position in space. Two studies investigated the barbell's position and movement pattern using a 2D analysis [7,11]. The shape of the barbell path differed between these two studies despite both studies using the conventional deadlift. In Swinton et al. [11], the barbell path showed a smooth curve with 80% of 1RM. The start and end points of the lift were almost equal in displacement at 80% 1RM. Conversely, McGuigan et al. [7] employed maximal loads and demonstrated a markedly more abrupt curve towards the body following a relatively vertical ascent for the bar path. This phenomenon may be attributed to exaggerated trunk hyperextension at the conclusion of the lift when attempting to lift maximal loads.

CURRENT UNDERSTANDING OF EMG DURING DEADLIFT

Surface EMG measures the muscle activity of individual muscles or muscle groups from the skin's surface. EMG is useful for quantifying muscle activation levels and comparing them across different exercises.

Escamilla et al. [15] investigated the impact of the reduced ROM associated with the sumo deadlift on muscle activation by comparing it with the conventional deadlift. Their analysis of EMG data revealed that the VL, Vastus medidis (VM), and tibialis anterior exhibited increased muscle activation during the Sumo deadlift. This suggests that for individuals targeting the anterior lower limb muscle groups, the Sumo deadlift might be a more favorable choice compared to the conventional deadlift. In a study by Lee et al. [16], muscle activation of the lower limbs and joint kinetics were investigated to determine the superior training protocol between the conventional and Romanian deadlifts. Twenty-one males participated, performing each deadlift with 70% of their determined Romanian deadlift 1RM. The conventional deadlift demonstrated significantly higher normalized EMG values in the rectus femoris and GM compared to the Romanian deadlift. Moreover, the conventional deadlift exhibited greater knee and ankle net joint torque. This study suggested that the conventional deadlift is more effective for training lower limb muscles, including the rectus femoris and GM. The increased muscle activation observed in the conventional deadlift, attributed to significant rises in knee and hip flexion muscles during the process, likely led to greater effort from extension muscles such as the rectus femoris and GM. Despite the common belief that the Romanian deadlift primarily targets the hamstrings, this study found no significant difference in biceps femoris (BF) activation between the conventional and Romanian deadlift variations.

Furthermore, Bezerra et al. [17] also investigated studies analyzing EMG signals in the lower extremities and lower back during conventional and stiff leg deadlift exercises. All the study was conducted on males, and all of the exercises were conducted at 70% of the one repetition maximum. This research showed that VL implies more higher root mean square (RMS) values in deadlift, and medial gastrocnemius implied higher RMS values in stiff leg deadlift. As in the previous studies, Ebben et al. [18] investigated various resistance training exercises where hamstring muscle activation occurs particularly well. The exercises evaluated included the squat, seated leg curl, stiff leg deadlift, single leg deadlift, good morning, and Russian curl. Male and female professional college athletes participated, and their six-repetition max for each exercise was pretested. Results indicated varying levels of hamstring activation across exercises, with the Russian curl demonstrating the most heightened activation, followed by the seated leg curl, stiff leg deadlift, single leg deadlift, good morning, and finally, the squat. The study suggested that the Russian curl might be the optimal option for explicitly targeting the hamstrings, emphasizing that the squat was unsuitable for hamstring training. The collective findings from these studies imply that Russian curls, stiff leg deadlifts, and leg curls are more effective in hamstring training than the barbell back squat and other lower body exercises. The recommendation is to prioritize more specific movements for hamstring training rather than relying solely on back squats. However, additional research is warranted to comprehensively explore conventional deadlifts and other deadlift variations to understand muscle activation in the hamstrings and other lower body muscle groups.

Another study investigated the effects of band variable resistance exercise on muscle activation [19]. The study's findings indicated a significant decrease in muscle activity in the medial gastrocnemius and semitendinosus as band resistance increased. Conversely, there was a significant increase in peak and mean bar velocity and power with increasing band tension. Therefore, conducting the deadlift using a band was associated with heightened bar velocity and power, accompanied by reduced muscle activation in the posterior muscles. Trainers incorporating this exercise into their exercise program can consider supplementing it with additional posterior muscle exercises that have demonstrated efficacy in achieving high muscle activation levels.

Recently, a new technique has emerged in training, one of which is using Bosu to perform deadlift exercises in an unstable environment [20-22]. However, Chulvi-Medrano et al. [21] showed that performing deadlifts under stable conditions encourages greater production of muscle activation. Furthermore, when weight training exercises (back squat, deadlift, overhead press) are conducted on stable and unstable surfaces, the benefits of unstable surfaces have yet to be investigated [20]. As with the previous studies, unstable environments are not limited to the surface. Another approach is to use unstable loads to increase muscle activation and strength in the body, which is also gaining popularity. The difference between an unstable surface and an unstable load is where the instability is applied and how it is applied. In strength training, instability can arise either from an unstable surface, such as training on a BOSU ball, where the instability exists between the body and the surface, or from an unstable load, where the instability is between the unstable load and the body. Recent methods in strength training and conditioning have introduced various techniques, with two common approaches being the use of elastic bands for suspension or incorporating a flexible barbell. A study focused on squatting with an unstable load found increased activation of the rectus abdominis, external oblique, and soleus muscles. This suggests the significance of squatting with an unstable load in engaging stabilizing muscles during the exercise [23]. Another study found that bench pressing with unstable loads increased biceps activation. Despite using a lighter weight for the unstable load bench press, most stabilizer muscle activity did not differ significantly between stable and unstable conditions. This implies that the amount of weight employed during unstable load training may be constrained by the stabilizer muscles' capacity to control the load [14].

CONCLUSION

The comprehensive analysis of kinematics and EMG activity during deadlifts offers valuable insights for strength and conditioning, sports science, and sports medicine. Understanding the biomechanical and neuromuscular differences between deadlift variations, such as conventional and sumo deadlifts, allows for more effective and individualized training programs. For instance, the sumo deadlift's reduced lumbar stress is beneficial for athletes needing to minimize lower back strain, while the conventional deadlift's greater ROM aids in developing overall power. Incorporating hexagonal barbells and variable resistance training can enhance training variety and effectiveness. In sports medicine, these insights inform targeted rehabilitation and injury prevention strategies, allowing for the development of exercises that address specific joint angles and muscle activations. Overall, the detailed understanding of deadlift mechanics enhances performance optimization, injury prevention, and rehabilitation, providing a robust foundation for practitioners across these fields to develop precise and effective interventions tailored to the unique needs of athletes.

CONFLICT OF INTEREST

The author declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

AUTHOR CONTRIBUTIONS

Conceptualization: J Lee, E Chang; Data curation: J Lee, H Kim, S Ko; Formal analysis: J Lee, H Kim, S Ko; Funding acquisition: E Chang; Methodology: J Lee, E Chang; Project administration: J Lee, E Chang; Visualization: H Kim, S Ko; Writing - original draft: J Lee; Writing - review & editing: J Lee, H Kim, S Ko, E Chang.

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REFERENCES

1. Nigrox F, Bartolomei S. A comparison between the squat and the deadlift for lower body strength and power training. J HumKinet. 2020; 73(1):145-52.
2. Bird S, Barrington-Higgs B. Exploring the deadlift. Strength Cond J. 2010;32(2):46-51.
3. Schellenberg F, Taylor WR, Lorenzetti S. Towards evidence based strength training: a comparison of muscle forces during deadlifts, goodmornings and split squats. BMC Sports Sci Med. Rehabi. 2017;9:1-10.
4. Kasovic J, Martin B, Fahs CA. Kinematic differences between the front and back squat and conventional and sumo deadlift. J Strength Cond Res. 2019;33(12):3213-9.
5. Hales ME, Johnson BF, Johnson JT. Kinematic analysis of the powerlifting style squat and the conventional deadlift during competition: is there a cross-over effect between lifts? J Strength Cond Res. 2009;23(9): 2574-80.
6. Brown EW, Abani K. Kinematics and kinetics of the dead lift in adolescent power lifters. Med Sci Sports Exerc. 1985;17(5):554-66.
7. McGuigan MR, Wilson BD. Biomechanical analysis of the deadlift. J Strength Cond Res. 1996;10(4):250-5.
8. Graham JF. Exercise: deadlift. Strength Cond J. 2000;22(5):18.
9. Gentry M, Pratt D, Caterisano T. Strength training modalities: introducing the trap bar. Strength Cond J. 1987;9(3):54-6.
10. Shepard G, Goss K. Bigger faster stronger. Human Kinetics; 2017.
11. Swinton PA, Stewart A, Agouris I, Keogh JW, Lloyd R, et al. A biomechanical analysis of straight and hexagonal barbell deadlifts using submaximal loads. J Strength Cond Res. 2011;25(7):2000-9.
12. Israetel MA, McBride JM, Nuzzo JL, Skinner JW, Dayne AM, et al. Kinetic and kinematic differences between squats performed with and without elastic bands. J Strength Cond Res. 2010;24(1):190-4.
13. Galpin AJ, Malyszek KK, Davis KA, Record SM, Brown LE, et al. Acute effects of elastic bands on kinetic characteristics during the deadlift at moderate and heavy loads. J Strength Cond Res. 2015;29(12):3271-8.
14. Lawrence MA, Ostrowski SJ, Leib DJ, Carlson LA. Effect of unstable loads on stabilizing muscles and bar motion during the bench press. J Strength Cond Res. 2021;35:S120-S6.
15. Escamilla RF, Francisco AC, Kayes AV, Speer KP, Moorman 3rd CT, et al. An electromyographic analysis of sumo and conventional style deadlifts. Med Sci Sports Exerc. 2002;34(4):682-8.
16. Lee S, Schultz J, Timgren J, Staelgraeve K, Miller M, et al. An electromyographic and kinetic comparison of conventional and romanian deadlifts. J Eeerc Sci Fit. 2018;16(3):87-93.
17. Bezerra ES, Simão R, Fleck SJ, Paz G, Maia M, et al. Electromyographic activity of lower body muscles during the deadlift and still-legged deadlift. J Exerc Physiol Online. 2013;16(3):30-9.
18. Ebben WP. Hamstring activation during lower body resistance training exercises. Int J Sports Physiol Perform. 2009;4(1):84-96.
19. Heelas T, Theis N, Hughes JD. Muscle activation patterns during variable resistance deadlift training with and without elastic bands. J Strength Cond Res. 2021;35(11):3006-11.
20. Willardson JM, Fontana FE, Bressel E. Effect of surface stability on core muscle activity for dynamic resistance exercises. Int J Sports Physiol Perform. 2009;4(1):97-109.
21. Chulvi-Medrano I, García-Massó X, Colado JC, Pablos C, Alves de Moraes J, et al. Deadlift muscle force and activation under stable and

unstable conditions. J Strength Cond Res. 2010;24(10):2723-30.
22. Fozia SS, Sharma S, Arora N. Core muscles electromyographic analysis in collegiate athlete on performing deadlift on different unstable surfaces. IJFMP. 2019;12(2):95.
23. Lawrence MA, Carlson LA. Effects of an unstable load on force and muscle activation during a parallel back squat. J Strength Cond Res. 2015;29(10):2949-53.