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THE EFFECTS OF LOAD MASS ON THE KINEMATICS OF STIFF-LEGGED DEADLIFT

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The purpose of this study was to investigate the effects of load mass on the kinematics of lower extremity joint movements during the stiff-legged deadlift (SLD) lift exercise. Five participants performed the SLD at 40%, 60%, and 80% of their estimated 1 repetition maximum. Measurements of the joint angle and angular velocity of the spine, hip, knee, and ankle were analyzed to understand the influence of various load masses in the SLD lifting technique. No statistical significant differences were found in the joint angles and angular velocities of the spine and lower extremity between different loads. Therefore, this study suggests that performing stiff-legged exercise up to 80% is safe to perform as long as the participants are experienced with this lifting technique.

KEY WORDS: load, spine, strength training, weight lifting

INTRODUCTION: In the society today, methods to prevent injury are often incorporated into lifting regimens. This could include factors such as improving flexibility or correcting muscular imbalances through a variety of resistance exercises. However, when proper technique is neglected, the possibility of injury can be devastating especially to the lower-back. Additionally, Piper and Waller (2001) state that the stiff-legged deadlift (SLD) is a high-risk exercise performed in weight rooms but is commonly a contraindicated exercise due to potential risk to the intervertebral discs. Although in 1991, Punnett, Fine, Keyserling, Herrin, and Chaffin identified trunk flexion, observed in the SLD, as a risk factor for low back pain. Yet, about 20 years later, the lift is still implemented into most high school, university, and professional sports settings due to the ability to improve lower-body development if executed correctly. The SLD still remains one of the most misunderstood lifts that many individuals inadvertently perform improperly (Gardner and Cole, 1999). The human spine is very flexible due to the arrangement of stiff vertebral bodies interspersed by softer intervertebral discs (Meakin, Aspden, Smith and Gilbert, 2009). Factors such as the angle of the hip and knee joints and tightness of the leg and trunk muscles can influence spinal shape (Meakin et al., 2009). When the muscles of the trunk are already in a state of fatigue, inappropriate function in the form of improper muscle contractions and relaxation will occur. This muscle fatigue can be either central; failure of the nervous system to drive the muscle maximally, or peripheral; any process occurring at or distal to the neuromuscular junction, or within the muscle itself (Talebian, Hosseini, Bagheri, Olyaei, and Reazasoltani, 2011). Essentially these trunk muscles are referred to as the “core stabilizers” and must be well-conditioned to endure activities prone to risk of injury, especially low-back pain (Hamlyn, Behm, and Young, 2007). Research has yet to conclude the most efficient method to train the core muscles despite the correlation between lack of strength and endurance in the core muscles and prevalence of back disorders (Hamlyn et al., 2007). Ergo, a combination of core muscle fatigue, a flexible spine and a history of low-back pain in any degree can result in an increased risk of injury during resistance training. As previously mentioned, an individual with a weakened musculature of the core is more susceptible to injury. Therefore, an otherwise healthy individual should perform exercises to strengthen their core, specifically lumbar stabilization exercises, before engaging in difficult resistance exercises such as the SLD. Additionally, McGill (2010) states that a greater range of motion in an individual’s back but with limited range of motion in their hips can contribute to future back disorders. The lift itself stresses the spine since trunk flexion puts pressure on the intervertebral discs. Full spine flexion to extension with weight supported by the hands, as performed in the SLD, causes the lumbar discs to be placed under a great amount of torque. Due to the weak mechanical advantage caused by the long lever arm between the weight and the low back, the low back extensors produce forces in excess of 10 times the amount of weight lifted (Gardner and Cole, 1999). Therefore, it is suggested that a change in angular displacement and velocity will be seen as the load mass increases. Hence, the researchers hypothesized that as the load mass increased, a statistically significant decrease would occur in the angular displacement and velocity. The purpose of this study was to examine the lower-body kinematics during the stiff-legged deadlift exercise with variations of load mass. The results would help coaches and trainers to develop safer instruction on the mechanics of lifting and prescribe better strength and conditioning programs.

METHODS: Five male experienced weightlifters (mean: age 21.4 years; height 1.87 m; weight 97.9 kg; lifting experience 7.6 years) were recruited to participate in the study. The Institutional Review Board granted approval and written informed consent was obtained from each participant prior to the study. All participants arrived at the Exercise Physiology Laboratory. Barbells and weight plates were provided to the participants. The participants were each allowed to go through their usual warm up. After the participants warmed up, their 1 repetition maximum (RM) for the stiff-legged deadlift (SLD) was established through a 10 RM estimate. Minimal instruction was given to the athletes as to how to perform the lift since the purpose of the study was to note changes in lower-extremity joint angles and velocities. Therefore, athletes were told to perform the lift as they naturally would. The participants were then asked to return a week later to perform the SLD lifts. Reflective markers were placed on joints on the right side of the body, which included the fifth metatarsal (foot), lateral malleous (ankle), lateral epicondyle of the femur (knee), greater trochanter (hip), greater tubercle (shoulder), lateral epicondyle of the humerus (elbow), styloid process of the radius (wrist), spine (approximately T6, L3, and S1), chin, forehead and the barbell. Spine angle is defined as the degree between S1 and T6 with L3 serving as the fulcrum. The hip angle consists of the angle between the lateral epicondyle (knee) and the greater tubercle with the greater trochanter as the fulcrum. The lateral epicondyle (knee) serves as the fulcrum of the knee angle between the greater trochanter and the lateral malleous. The lateral malleous serves as the fulcrum for the ankle angle between the lateral epicondyle (knee) and the 5th metatarsal. Each participant was asked to remove their shirt to eliminate movement of reflection markers, particularly on the spine, and to wear black shorts to ease the sight of the markers. Each participant performed their usual warm-up. The SLD was then performed at 40%, 60% and 80% of their estimated 1RM in a randomized order to reduce order effect. Six repetitions at each load were performed. Due to the delicacy of the lift, a true 1 RM was not warranted. Additionally, 40%, 60%, and 80% are indicative of intensity in relation to the true 1 RM. Typically a load of 80% can be correlated with 8 repetitions. In order to further minimize the risk of injury, 6 repetitions were performed at 80% rather than 8 repetitions, and these same parameters were chosen for 40% and 60%. Participants took at least a 5 minute break in between the different loads in order to allow the restoration of their ATP stores and to eliminate any notion of muscle fatigue attributing to changes in technique. The risk of injury in performing the SLD was minimized because these participants were experienced and familiar with the lift. Data collection was conducted in one session with an hour in duration. Position-time data were recorded with a JVC video camera (Model: GR-D371V) capturing the movement at 60 frames per second in the sagittal view. A 650W artificial light illuminated the joint reflective markers. The video was then transferred onto a computer in the Biomechanics Laboratory. A standard two-dimensional kinematic analysis was conducted with Ariel Performance Analysis System software and focused on the "sticking point" of each lift, i.e. the lowest position of the participant during the lift. The first and last repetitions of each six repetition lift were discarded due to acclimation and fatigue, respectively. Of the remaining four lifts to analyze, three were chosen at random. Also, the digital filter function was applied to data at 8 Hz. Paired sample t-tests were conducted at $\alpha = 0.05$ with Bonferroni adjustment. All statistical analyses were conducted with SPSS (v. 18) software.

RESULTS and DISCUSSION: A paired sample t-test was conducted between loads within the SLD technique in relation to the spine, hip, knee and ankle angular displacement. No significant differences were found between changes of load within the lift in the hip, knee, and ankle. Of particular interest was the spine due to potential for injury. Results indicated the participants kept the natural lumbar curve, Table 1. Therefore, the participants maintained the same technique even with an increase of load. Additionally, when evaluating at the angular velocity, no significant statistical differences were found in all joints, which indicates that regardless of the load of the barbell, the participants executed the lift at relatively the same speed. Despite instruction for performing the SLD technique typically involves maintaining a "flat and not rounded lower back," it could be suggested that the natural lumbar curve should be maintained throughout the lift. Although research has not been conducted to discuss lumbar spine position in the SLD, controversy has arisen in back squats, in which the exercise can be performed the full depth as long as the normal lordotic curve is kept (McKean et al., 2010). Since no significant statistical differences were found, these findings suggest that experienced weightlifters are generally safe to perform stiff-legged deadlift exercise at 40%, 60% and 80% as long as a natural lumbar curvature is kept.

Table 1
Spine Angular Displacement

Comparisons	Mean (SD)	*p*
Spine 40% - Spine 60%	171.9 (4.2)° vs. 170.4 (4.1)°	.256
Spine 40% - Spine 80%	171.9 (4.2)° vs. 170.8 (4.4)°	.505
Spine 60% - Spine 80%	170.4 (4.1)° vs. 170.8 (4.4)°	.812

Statistical significant at $p < 0.017$

In terms of angular velocity, it can be suggested that the weightlifters would perform the SLD with a heavier weight more slowly considering speed of execution is not crucial. However, this study did not find any statistical significant differences in angular velocity between the changes in load. A general trend was noticed in relation to angular velocity, in which the weightlifters performed each lift with careful execution regardless of mass. As elite weightlifters, this further shows the delicacy of the lift and emphasis on proper technique.

CONCLUSION: This study provides a preliminary understanding on the lower body kinematics of the stiff-legged deadlift. These findings suggest that this lifting technique is safe to perform when a natural lumbar curvature is kept. It is also imperative to consider the participants performing this lift are experienced. Special consideration should be given to those just beginning to lift and emphasis should be placed upon proper technique, especially of the spine to avoid injury. Given the nature of the exercise, one could suggest initially performing the SLD at lighter loads for the purpose of increasing lower-body strength and flexibility. However, as a weightlifter gains experience in the lift, heavier loads are warranted. When done correctly, these lifts can be extremely beneficial to lower-body development and remain productive for athletes. Future studies are warranted to examine other methods (i.e. over the shoulder) of performing stiff-legged deadlift to have a more comprehensive understanding about this lifting exercise.

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