Improving the Deadlift: Understanding Biomechanical Constraints and Physiological Adaptations to Resistance Exercise

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SUMMARY

IN THE SPORT OF POWERLIFTING, INCORRECT INFORMATION REGARDING MUSCULAR STRENGTH DEVELOPMENT MAY BE PERPETUATED BY VARIOUS SOURCES. ONE WAY TO COMBAT THIS PROBLEM IS TO PROVIDE CORRECT BIOMECHANICAL AND PHYSIOLOGICAL INFORMATION REGARDING LIFTS SUCH AS THE DEADLIFT TO ENHANCE PERFORMANCE IN THE SPORT. THERE ARE 3 SPECIFIC AREAS THAT CAN BE ADDRESSED TO IMPROVE DEADLIFT PERFORMANCE: SUPPORTIVE GEAR, LIFTING MECHANICS, AND TRAINING PRINCIPLES. THIS ARTICLE OFFERS SUGGESTIONS TO ENHANCE PERFORMANCE IN THE DEADLIFT BY PROVIDING INSIGHT INTO PHYSIOLOGICAL ADAPTATIONS AND BIOMECHANICAL CONSTRAINTS ASSOCIATED WITH STRENGTH DEVELOPMENT.

INTRODUCTION

Because the deadlift is 1 of the 3 events performed in powerlifting and maximizing the lift is extremely important to the outcome of a competition, much of the discussion will center on the sport. However, any sport that places high demand on strengthening knee, hip, and trunk extensors could benefit from incorporating the deadlift into the training program. Anyone unfamiliar with the intricacies of the deadlift could easily assume that it is simple to execute, which basically requires nothing more than bending down, grasping a barbell, and standing up. A movement pattern simple in appearance should not be judged entirely based on perception because the complexity of mastering proper lifting technique and implementing the correct training program demonstrate exactly how challenging it can be to maximize performance, and the deadlift is one of those exercises.

A common statement that regularly circulates throughout the powerlifting community is "great deadlifters are born–not made." So, it is not uncommon for athletes to blame a less than optimum deadlift on poor genetics. This mind-set could certainly play a role in preventing competitors from striving to reach their peak in muscular strength. Each biological system in the human body has a physiological ceiling that is influenced by not only genetic encoding but also impending environmental factors as well. The genetic component only accounts for about 40–50% for the proportional factor of muscle fiber type (slow twitch versus fast twitch), 30–70% for heart size and cardiac functions, and around 30–50% for maximal oxygen consumption and utilization (7,8,16). Other characteristics that have a genetic component include metabolic rate, blood volume, flexibility, anaerobic performance,

KEY WORDS:
powerlifting; deadlift; biomechanical constraints; physiological adaptation

body fat distribution, and endocrine status–that is, level of testosterone secretion (20,33). These genetic values suggest that approximately 50–75% of the overall deadlift performance could be attributed to environmental factors such as training methods, lifting styles, and individualized program parameters. Assuming a lifter has not peaked physiologically in the areas contributing to strength development, deadlift performance has the potential for improvement.

FIRST–THE PROBLEM

A growing problem in the sport of powerlifting centers around the available resources focusing on muscular strength development, lifting technique, and program design. In many instances, the circulating information in sources other than peer-reviewed sport science journals fails to provide a reasonable scientific foundation for implementation. One way to rectify this issue in the sport of powerlifting is to simply provide scientifically supported biomechanical principles and physiological concepts targeting resistance exercise and program design for enhancing deadlift performance.

Understanding the body's mechanical properties and skeletal muscle adaptation to various stimuli is important for designing strength training programs. This implies that any applicable biological system that has not yet peaked has additional muscular strength reserves and is capable of contributing to the improvement of deadlift performance. However, a challenge for an athlete or the strength specialist is determining how to access the available reservoir of resources. This article discusses 2 areas of importance about strength development: biomechanical factors and physiological adaptations associated with improving deadlift performance.

BIOMECHANICAL FACTORS

There are 2 basic deadlift styles–conventional and sumo. However, few powerlifters seldom use one style or the other, in a strict sense. From a performance standpoint, one lifting style does not appear to be more advantageous mechanically than the other based on the total number of conventional and sumo style deadlift record holders (1,51). To maximize deadlift performance, the strength coach should explore the different lift types and find a style that is most appropriate for the athlete. To facilitate the selection process, the strength and conditioning specialist could benefit from developing an understanding of the interrelationship between muscle architecture, anthropometrics, and fiber number and composition.

DEADLIFT MECHANICS

The following terms commonly associated with weight training are frequently used interchangeably, which is often confusing to the reader. To assist with describing deadlift mechanics, standardized terminology adopted by the sport science community is implemented.

- Style: A way of doing something; implementing a particular method.
- Technique: The procedure or skill used in a particular task.
- Strategy: A plan of action designed to achieve a particular goal.

An individual's lifting style should be based on their anthropometrics and not on someone else's physical characteristics (i.e., workout of the month). However, choosing the appropriate lifting style is not an easy task. Even though gross lifting guidelines (position the barbell close to the body, maintain lumbar lordosis, keep elbows fully extended, etc) apply to everyone, the minute details associated with an optimal lifting style can vary greatly between individuals.

Technique is important when deciding whether the barbell should be lifted using a leg-lift, back-lift, or a modified back-lift strategy when performing a maximum effort conventional style deadlift (Figure 1). Most of the information pertaining to lifting technique has been derived from research incorporating inexperienced lifters using light to moderate weight (4,14,15). The outcomes of these studies using submaximal loads indicate that the leg-lift method is the preferred lifting strategy (4,49,50). However, under maximum loading conditions typically observed during powerlifting competitions, lifters exhibit a different lifting technique resembling the modified back lift (15,21,26).

The primary concerns of lifters using the conventional style deadlift are excessive trunk lean and premature knee extension at the start of the lift (26). A maximum effort deadlift demonstrates a sequential or segmented lifting movement divided into 3 distinct phases depicting the predominant joint action: knee extension, hip extension, and knee/hip extension (26). Knee extension occurs before barbell liftoff due, in part, to the quadriceps muscles' inability to generate an extensor muscle moment large enough in magnitude to overcome the inertia of the lifter-barbell system (21,26). However, once the segments of the lower extremities reach an optimum angle for exerting maximal force, the potential for lifting the barbell increases because of muscle force production factors such as muscle angle of pull and length-tension relationship. Excessive trunk lean exhibited during this portion of the deadlift reduces the external flexor moment at the knee joint, which results in less quadriceps effort. However, the trunk position elicits a large hip extensor moment (49).

In summary, when performing extremely heavy conventional style deadlifts, using the leg-lift method does not appear to be the preferred strategy or maybe even possible (21). In addition, the ability to maintain lumbar lordosis diminishes as the lifting loads increase due, in part, to the force magnitude of the erectors' inability to overpower the high forces generated by the hip extensor muscles at the initial phase of the lift (21). When executing maximum effort conventional style deadlifts, the lifter typically exhibits either a back-lift or a modified back-lift technique with a slightly exaggerated kyphotic thoracic curve (21,26). The modified back-lift technique provides an advantage to the lifter in terms of performance

Figure 1. Deadlift lifting strategies (conventional style). (a) Modified back lift. (b) Leg lift. (c) Back lift.

because the barbell is positioned closer to the hip and lumbosacral joints resulting in a reduced external flexor moment. However, the technique creates a disadvantage regarding enhancing the injury potential to the ligaments because of the high stresses placed on the spinal ligaments (28,31).

The sumo style deadlift exhibits different lifting mechanics while using a leg-lift, back-lift, or a modified back-lift technique (Figure 2). Because of the wide stance used during a sumo deadlift, the mass center of the upper body is positioned closer to the barbell that decreases the external flexor moment at the knee, hip, and L5/S1 joints (14,15,49). Knee extension is not a predominant movement at the start of the sumo style lift because of the location of the barbell, which places the quadriceps in an optimal position for exerting greater force magnitude while incorporating a wide stance (14). The

Figure 2. (a–c) Deadlift lifting strategies (sumo style). (a) Modified back lift. (b) Leg lift. (c) Back lift.

knee and hip extensors contract at a similar rate and work in a synergistic manner to overcome the external flexion moment exerted by the lifter-barbell system.

An important aspect often neglected concerning the sumo style is the larger mediolateral (shear) ground force component compared with the conventional style deadlift. The ground force distribution associated with the sumo style could negate the advantages associated with the barbell load center location and the lifter's mass center relationship.

The sumo style lift exhibits similar biomechanical issues that are observed during the conventional style deadlift (14). However, under maximum effort conditions, the lifter typically uses a leg-lift or modified back-lift strategy. Lordosis is easier to maintain while using the sumo style compared with the conventional style deadlift because the hip extensor muscle moment generally does not exceed the force magnitude generated by the erectors spinae muscle (14,15,21). Research indicates that less tensile stress is placed on the posterior ligament system when lifting an object from the floor while maintaining lumbar lordosis (13,28,30,31,40,41,45,46).

In summary, the objective of the article is not to argue against these points rather to point out that it is extremely difficult or even impossible to maintain lumbar lordosis during the execution of maximum deadlifts. In addition, maximum deadlifts tend to cause an over exaggerated kyphotic curve of the thoracic spinal region, which has received minimal amounts of attention in the past because of the limited amount of research using 1 repetition maximum (1RM) deadlifts. These body positions may be unavoidable while executing maximum deadlifts, so targeting the appropriate muscle groups during training and replicating the lifting technique demonstrated in competition is extremely important to maximizing strength.

GUIDELINES FOR SELECTING THE OPTIMAL LIFTING STYLE

Many anatomical and physiological parameters, such as segmental lengths and muscle fiber composition and number, are extremely difficult or impossible to alter (38,39). However, each lifter does have the ability to explore different lifting styles and implement a training program to accentuate their physiological and biomechanical characteristics. Table 1 lists various anthropometric combinations and lifting style recommendations. The selection process should also consider an individual's biomechanical and physiological limitations.

The segmental lengths defined in Table 2 are based on the individual's overall height (11). The segments are labeled according to the diagram (Figure 3) depicting the anatomical position. Specific anatomical landmarks are used to measure the length of the individual segments. Leg length is defined from greater trochanter to the lateral aspect of the foot. Arm length is defined from humeral head to the tip of the third finger. The torso is defined from the greater trochanter to an imaginary line extending horizontally from the top of the head.

The guidelines presented in Table 2 for selecting an optimal deadlifting style are based entirely on the individuals' segmental lengths. One must also consider the muscle groups with the greatest capacity for developing maximum strength. The conventional style deadlift generates large hip extensor moments, whereas the sumo style deadlift generates both knee and hip extensor moments in addition to hip adductor moments (15). A lifter with strong knee and hip extensors and above average hip flexibility should consider using the sumo style deadlift. If the lifter has strong hip and trunk extensors but less than average hip flexibility, he or she might consider using the conventional style.

Table 1
Lifting strategy determinants

Segment combinations	Conventional	Sumo
Elongated torso/short arms		X
Elongated torso/elongated arms	X	
Short torso/short arms		X
Short torso/elongated arms	X	
Average torso/short arms		X
Average torso/elongated arms	X	
Short torso/average arms	X	X
Elongated torso/average arms	X	X

Table 2
Segment lengths expressed as proportion of body stature (A)

	Average (%)	Above average (elongated) (%)	Below average (short) (%)
Torso (B)	32	>32	<32
Legs (C)	49	>49	<49
Arms (D)	38	>38	<38

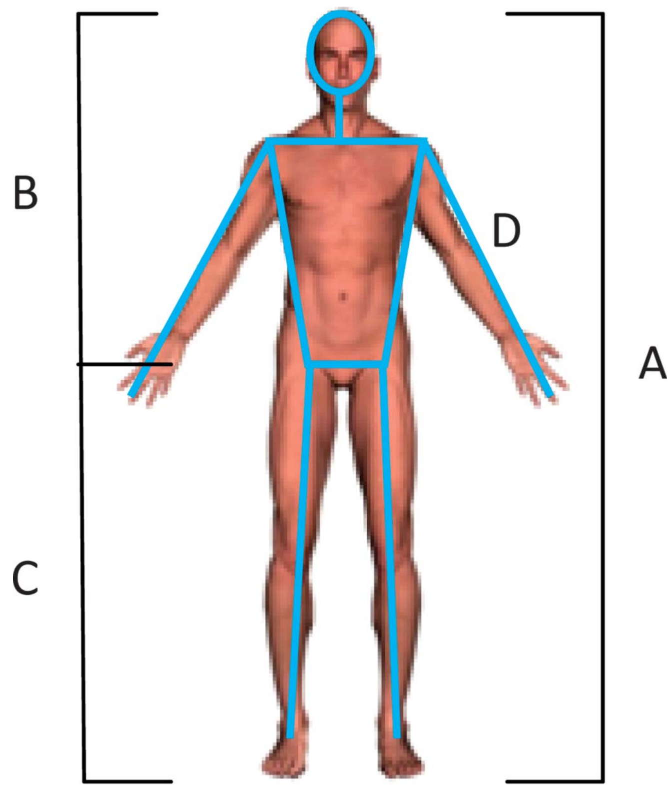

Figure 3. Segmental lengths. (a) Total body height. (b) Torso. (c) Legs. (d) Arms.

PHYSIOLOGICAL ADAPTATIONS

The protocol of a heavy resistance training program has a direct impact on the body's physiological responses and adaptation processes. Athletes and coaches involved in powerlifting could benefit from understanding the interrelationship between the endocrine, neural, and skeletal muscle systems and learn how to take full advantage of the systems to maximize muscular strength development through exercise selection and program design.

HORMONAL RESPONSE

One problem lifters experience with consistently using the same exercises and repetition/set scheme in a resistance training program is that only a specific set of muscle fibers associated with that movement are activated and stimulated to increase strength. Studies have reported that the volume of work and the type of protocol are vital to the muscle response pattern and magnitude of hormonal changes in individuals (22,24,34,35). The amount of hormonal secretion depends on several factors such as the amount of muscle tissue recruited, remodeled, and repaired consequent to the training emphasis (34). Thus, the characteristics of the exercise program are extremely important to the hormonal response of the musculoskeletal system, and a key anabolic hormone responsible for muscle strength and growth is testosterone. There are several exercise program components directly responsible for increasing serum testosterone concentrations (17,18,36,37). To elevate the anabolic levels, a great deal of emphasis should be placed on exercises that use the large muscle groups (i.e., deadlifts), heavy resistance (80–90% of 1RM), moderate volume (2–3 sets), and long rest intervals (3–5 minutes); all are going to contribute the development of muscular strength (6).

MUSCLE ADAPTATION

Maximizing muscle recruitment is not an easy process because the fast-twitch muscle fibers have a high threshold for stimulation. A normal person can only, by a voluntary contraction, exert 60–70% of their absolute strength potential (12). Therefore, the autonomic reserves are not fully accessed but a properly designed and implemented program could potentially boost the absolute strength value to around 80–90% and in a small number of lifters possibly even higher (43). This is an important resource that few powerlifters rarely take complete advantage of, but it is definitely attainable with maximum effort and proper training.

The high-threshold fast-twitch (IIx) muscle fibers are often referred to as reserve fibers; in other words, fibers available for a fight-or-flight response (9,10). Theoretically, to recruit these muscle fibers during training, the exercise stimulus must elicit a similar response. Under those circumstances, one would assume that the weight must be extremely demanding to recruit the maximum number of motor units. Heavy resistance training elicits the recruitment of type IIx muscle fibers, which are eventually transformed to type IIa muscle fibers. Conversely, the IIa fibers convert back to IIx muscle fibers during a detraining period (2,9,35,39,44). It is believed that the reversion occurs at an accelerated rate as opposed to the large to small transformation (12). This concept supports a tapering phase of training before competition. Low-repetition (2–5) work provides the optimal range for muscle fiber type adaptation and strength development (3,27,29,30).

The motor units of a muscle are generally recruited in a set order (slow twitch to fast twitch) in accordance with the size principle (48,52). As more force is demanded by an activity, progressively larger motor units are recruited (32,46). This is a common concept that most people misinterpret. Because the largest motor units are recruited last, most lifters equate that with meaning the end of a set. However, this notion is incorrect because muscle fiber activation is highest during the first portion of a set. As the set progresses, fast-twitch muscle fibers begin to fatigue and the load becomes more difficult to lift.

NEUROLOGICAL ADAPTATIONS

Neural adaptations are attributed to motor learning and improved synchronization of motor unit firing, which could lead to an increase in the force production. It is speculated that muscle firing order can be manipulated through heavy resistance and explosive exercise movements (42). A properly designed exercise program protocol could alter the firing order and actually bypass the slow-twitch muscle fibers and stimulate the fast-twitch fibers (2). Ultimately, the nervous system will become more efficient during this process, so in essence, the muscular system will be used to lift the heavier weight with greater efficiency by coordinating all the muscle fibers into 1 maximum effort. Maximal force production requires not only the recruitment of a maximal percentage of available motor units, including the high-threshold motor units, but also the recruitment of these motor units at very high firing rates (5). Once a motor unit is recruited, less activation is needed in order for it to be re-recruited (19). This concept may have important ramifications for strength training because these high-threshold motor units may be more readily reactivated subsequent to previous recruitment. In advanced powerlifters, the central nervous system might adapt by allowing these athletes to recruit some motor units not in consecutive order, recruiting larger ones first to help with greater production of force in a movement.

The body has a built-in protective mechanism that causes the skeletal muscles to stop contracting before they exert their full potential against a heavy resistance to prevent soft tissue injury. Research suggests that some form of inhibition may limit complete muscle activation during heavy explosive weightlifting (23,25,47). It is speculated that the neuromuscular adaptations are attributed to either a decrease in the inhibitory function of the central nervous system, decreased sensitivity of the Golgi tendon organs, increased motor unit recruitment or synchronization, or changes at the neuromuscular junction of the motor unit (9,10). The exact cause is unclear, but many in the sport science community believe that the inhibition mechanism can be overcome by a properly implemented heavy resistance training program (42,44).

CONCLUSION

The article lays the foundation for designing an individualized heavy resistance training program for maximizing the deadlift. There are untapped strength reserves in the human body, but the challenge is identifying and using those hidden assets. Through years of proper resistance training, the body will be capable of producing a more coordinated, synchronized, and possibly reordered muscle fiber firing pattern, which could contribute to maximizing muscle force production.

Generally, humans are limited in the amount of force they are able to generate due, in part, to the poorly designed internal leverage system. To overcome this disadvantage, an individual will reduce excessive external moments by altering body position. Identifying the appropriate lifting style and implementing correct technique is paramount for maximizing deadlift performance. It is the first aspect to be resolved before a training regimen can be implemented. It is important to note that both conventional and sumo style deadlifts have both advantages and disadvantages associated with lifting mechanics. In many instances, the disadvantages attributed to a particular lifting style negate the advantages, so it is imperative that the lifter selects the style that accentuates their individualistic physical characteristics.

Finally, performing maximum deadlifts places extremely high tensile stress on the posterior ligamentous system of the spine, which could create a potential injurious situation. Maximum deadlifts should be performed with great caution and executed on a limited basis; preferably, 1RM deadlifts should only be performed by strength athletes.

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