BACK STRESS AND ASSISTANCE EXERCISES IN WEIGHTLIFTING

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The purpose of this study was to test the suitability of selected assistance exercises to strengthen the low back for the Olympic lifts in high level weightlifters. Four subjects were filmed by a five-camera Motion Analysis system operating at 120Hz completing both of the Olympic lifts (Snatch and Clean) and four assistance exercises (Romanian Deadlift (RDL), Bent-over Row (BOR), Clean Pull Deadlift (CPD), and Good Morning (GM)). Peak Erector Spinae Force (ESF) and L5/S1 compressive and shear force (L5/S1 CF and L5/S1 SF respectively) were calculated via a top-down inverse dynamics model. Comparisons between the lifts were made using a one-way ANOVA with repeated measures. It was found that the CPD produced higher ESF than the Snatch but this exercise also produced very high L5/S1 CF and L5/S1 SF. The Clean also displayed a higher ESF than the Snatch. When normalising the data to bar weight, the BOR and GM was shown to potentially produce high ESF but coaches should consider the possibility for these exercises to produce low back injury.

KEY WORDS: weightlifting, inverse dynamics, assistance exercise, low back, strength.

INTRODUCTION: Olympic Weightlifting consists of two disciplines, they being the Snatch and the Clean and Jerk. The so-called "Olympic lifts" are routinely used in strength and conditioning programs at the elite level, and to a lesser degree in the recreational fitness industry. Previous research has identified Olympic lifting as an activity that produces very high power outputs. For example, lifters have produced power values for the Snatch of 1300 Watts in the 52kg class and up to 3000 Watts in the unlimited class (Garhammer, 1980). Correct technique in the Olympic lifts is of paramount importance to maximise power output to the desired musculature and prevent injury. Correct technique demands that the shoulders remain either over or ahead of the bar for as long as possible. The athlete should have the feeling of opening the knee joint whilst keeping the trunk at a constant angle relative to the horizontal. Therefore, for the athlete to be capable of adopting good technique when approaching near maximal efforts, the low back must have sufficient strength to keep the body in the correct position as described above. Further, the risk of back injury is high in these lifts if the lower back is not sufficiently conditioned. In weight training parlance exercises that prepare specific body parts for impending higher loads, are termed "assistance exercises". Assistance exercises can be performed with greater weight on the bar but the potential for these assistance exercises to provide a greater demand on the low back in preparation for loading in the Olympic lifts is unknown to date. Estimates of the loading on the lumbar spine during lifting can be made at one of the lower lumbar intervertebral joints via a computer modelling approach. Variables typically examined are the erector spinae force (ESF), in addition to the compressive and shear forces, which are derived from the reactive moment. The purpose of this study was to utilise a top-down inverse dynamics model to assess the suitability of commonly used assistance exercises to develop low back strength in athletes performing the Olympic lifts.

METHOD: Four male nationally ranked weightlifters (mean age = 21.5 years, mean height = 172.2 cm and mean mass = 94.1 kg) were recruited for this study. Each subject performed the Olympic lifts (Snatch and Clean) at a near one repetition maximum, followed by the four assistance exercises with a mass on the bar used during a typical training session. The assistance exercises that were analysed were the Romanian Deadlift (RDL), Bent-Over Row (BOR), Clean Pull Deadlift (CPD), and the Good Morning (GM). This constituted 24 trials in total (4 subjects x 6 lifts/subjects). Subjects performed the Snatch and Clean in sequence after which the assistance exercises were tested in a randomised order. The Mean (±SD) of the mass on the bar for the Clean was 128.7±13.1 kg and for the Snatch was 110.0±8.2 kg. For the assistance exercises the mass on the bar was 125.0±26.5 kg, 73.7±4.8 kg, 182.5±22.2 kg and 67.5±22.2 kg for the RDL, BOR, CPD and GM respectively. Each subject had retro-reflective markers attached to nine points on the right side of the body. Landmarks identified were the shoe tip, heel, ankle, knee, hip, seventh cervical vertebra (C7), shoulder, elbow and centre of the bar (Figure 1). To provide known 3-D control points, a calibration frame with dimensions of approximately 2.0m x 2.0m x 2.5m was centred over the desired lifting area. Subjects were filmed performing all lifts by a five camera Motion Analysis System (Motion Analysis Corporation, Santa Rosa, CA) operating at 120Hz. Following the identification of joint markers, video records were automatically digitised and the 3-D points reconstructed. These raw data were smoothed using a fourth-order low pass Butterworth digital filter with a cut off frequency of 5Hz and acceleration data were calculated via finite differences (Winter, 1990). L5/S1 joint kinetics were calculated via a dynamic nine-segment top-down link segment model. A dynamic model was deemed necessary as both the Clean and Snatch are both fast in nature and a static model would have underestimated the magnitude of the forces calculated (McGill & Norman, 1985). Customised software utilising Newtonian mechanics was written using LabVIEW V5.1 (National Instruments, TX, USA). Segmental inertia data was derived from deLeva (1996) and the L5/S1 joint was located using the data of Nemeth & Ohlsen (1989). The sacral cutting angle (angulation of the surface of the vertebrae) was calculated using the trunk and knee angles (Chaffin & Anderson, 1991 – the error in the formula provided in the text was altered after personal communication with Don Chaffin). The sacral cutting angle was necessary to convert forces in the global coordinate system to those in the vertebral coordinate system. To calculate the ESF a single equivalent muscle model was used with the moment arm being 6 cm and a line of action of 5° with respect to the compressive axis of the spine (Cholewicki et al., 1991). The L5/S1 compressive force (L5/S1 CF) and shear force (L5/S1 SF) were then calculated. Data were also normalised by dividing peak ESF and L5/S1 CF and SF by bar weight to account for the difference in bar mass between each exercise. No normalisation was performed considering body mass as the purpose of the study was to determine the differences in selected kinetic variables within subjects. A One-Way ANOVA with repeated measures using Statistical Package for Social Sciences (SPSS) was used to determine whether significant differences existed between the exercises examined. As there were six ANOVA's performed, the alpha level was adjusted to 0.008 (0.05/6) using the Bonferroni procedure. Post-hoc differences between means were determined via Least Squared Differences.

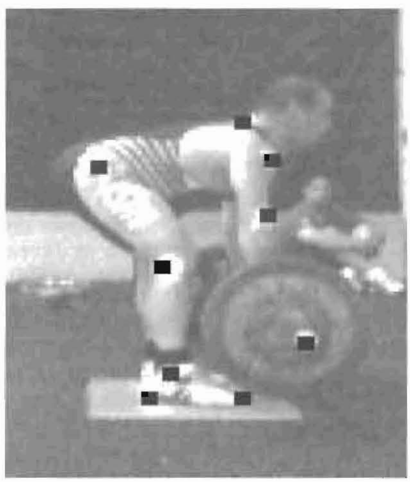

Figure 1. Anatomical landmarks used for the link segment model.

RESULTS AND DISCUSSION: A limitation of this study was that the eccentric (lowering) phase of the RDL, BOR and GM could not be considered (Kingma et al., 2001). EMG may have been a more appropriate method to examine the eccentric phase of these lifts (Dolan & Adams, 1993). The purpose of low back assistance exercises in weightlifting is to strengthen the back muscles so that an increased load can be lifted during the first pull with correct technique. There are more than likely exercises that will increase back muscle strength, but a consideration in improving a muscle group's functional performance is the risk of injury to the surrounding musculoskeletal structures. The L5/S1 CF and L5/S1 SF are variables that are commonly examined in biomechanics to determine the potential for injury. It is known that the spine can withstand very high compressive forces. For example, Cholewicki et al. (1991) calculated compressive forces up to 17,192N in elite powerlifters. Excessive lower lumbar shear forces can cause injury to the facet joints and the intervertebral disc. ESF, L5/S1 CF and L5/S1 SF were all derived from the L5/S1 moment. Cholewicki et al. (1991), using a quasi-static model, reported a peak L4/L5 moment of 538.8 N·m in a Deadlift with an average load of 190 kg. This compares favourably with the results found in this study as the peak L5/S1 moment calculated during the CPD of 495.9 N·m with a mean load of 182.2 kg. Further, it was found that in all lifts from the floor, the peak moment was achieved when the bar just cleared the floor, which supports research conducted on the pull in Weightlifting by Enoka (1979).

Table 1. Mean (±SD) Absolute and Normalised Peak L5/S1 Erector Spinae, Compressive and Shear Forces for Olympic Lifts (Clean and Snatch) and Assistance Exercises (RDL: Romanian Deadlift, BOR: Bent Over Row, CPD: Clean Pull Deadlift, and GM: Good Morning).

	Clean	Snatch	RDL	BOR	CPD	GM
Peak Erector Spinae Force (N)	7444.2^{b} (1811.9)	5773.6 (1202.7)	5696.2 (1514.9)	6857.3 (1035.3)	$8296.1^{b,c,f}$ (916.8)	5929.6 (1126.4)
Peak L5/S1 Comp. Force (N)	8568.8 (1825.3)	7019.5 (1462.9)	6700.9 (1584.7)	7687.1 (1119.3)	$9829.9^{b,c,d,f}$ (965.9)	6712.7 (1275.1)
Peak L5/S1 Shear Force (N)	1175.5 (210.7)	1064.9 (112.3)	$1961.9^{a,b}$ (521.5)	1397.6 (223.8)	$2338.5^{a,b,f}$ (767.8)	1227.8 (282.2)
Normalised Peak Erector Spinae Force	5.85 (0.90)	5.34 (0.94)	4.61 (0.32)	$9.57^{c,e}$ (1.96)	4.64 (0.18)	$9.43^{c,e}$ (2.21)
Normalised Peak L5/S1 Comp. Force	6.74 (0.80)	6.50 (1.11)	5.45 (0.30)	$10.73^{a,c,e}$ (2.14)	5.51 (0.16)	$10.66^{c,e}$ (2.37)
Normalised Peak L5/S1 Shear Force	0.93 (0.08)	0.99 (0.08)	1.61^{a} (0.40)	$1.92^{a,b,e}$ (0.19)	1.28 (0.31)	$1.91^{a,b}$ (0.22)

[a] denotes significantly different to the Clean ($p<0.008$).
[b] denotes significantly different to the Snatch($p<0.008$).
[c] denotes significantly different to the Romanian Deadlift (RDL) ($p<0.008$).
[d] denotes significantly different to the Bent-Over Row (BOR) ($p<0.008$).
[e] denotes significantly different to the Clean Pull Deadlift (CPD) ($p<0.008$).
[f] denotes significantly different to the Good Morning (GM) ($p<0.008$).

The absolute and normalised peak ESF, L5/S1 CF and L5/S1 SF for the Olympic lifts and the assistance exercises are presented in Table 1. These results showed that the absolute ESF values for the CPD were significantly higher ($p<0.008$) than the Snatch, RDL and GM. The Clean also showed a significantly higher ($P<0.008$) ESF than the Snatch. Whilst considering the CPD obviously produces high ESF, a potential drawback of the exercise is that is also produces very high L5/S1 CF and L5/S1 SF. From examining the normalised data it is more of a problem with the large mass on the bar (approximately 42% greater than that lifted during the Clean) rather than body position during the exercise. The RDL displayed a significantly greater ($p<0.008$) L5/S1 SF than both of the Olympic lifts. Given that the RDL produced the lowest ESF, it seems that this exercise has little to recommend it. In saying this however, one should bear in mind that the method of analysis used in this study does have it's disadvantages. It would have been interesting to analyse this exercise using EMG to determine the loading on the erector spinae musculature during the eccentric phase of the exercise. From examining the normalised data it is evident that the BOR and the GM are exercises which require a lesser mass on the bar to produce high ESF. The drawback with these exercises however was that they produced relatively high L5/S1 CF and L5/S1 SF. Therefore, coaches should use these exercises as variety in combination with other assistance exercises rather than as an end in themselves. If these exercises had been analysed with increasing bar mass it would have been possible to determine what mass would have been necessary to overload the erector spinae group.

CONCLUSIONS: From the results and within the limitations of the study, it can be concluded that the CPD can produce significantly higher ESF than the Snatch and Clean. Coaches should be mindful that the CPD should be performed with correct technique in order to reduce the possibility of injury as L5/S1 CF and L5/S1 SF are large in this exercise. The BOR and GM may also produce higher ESF than the Olympic lifts with a greater mass on the bar than was analysed in this study however, it should be stressed that these exercises do produce high levels of L5/S1 CF and L5/S1 SF.

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