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IMPULSES AND GROUND REACTION FORCES AT PROGRESSIVE INTENSITIES OF WEIGHTLIFTING VARIATIONS

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Five Division-I athletes who routinely performed the hang clean and hang snatch performed a single repetition of each at loads of 50, 60, 70, 80, and 90% of their 1 RM, with 5 minutes rest between each repetition. Movement impulses and peak GRF were evaluated on an AMTI force plate. Two-way ANOVA indicated impulses and peak GRF at 50% 1RM were lower than all other reps ($p<0.05$) and that 60% RM was less than 80% and 90%. Also the 70% repetition was less than 90% RM ($p<0.05$). Despite the fact that the 1RM loads were 50% higher for the hang clean than the hang snatch (133 vs. 88 kg), no differences in impulse were found between the two exercises ($p>0.05$). These results suggest other variables such as exercise form and movement velocity mediate the amount of impulse and/or force developed.

KEY WORDS: hang clean, hang snatch, power.

INTRODUCTION: Anecdotal observations and previous research suggest that Olympic style weightlifting (weightlifting) is useful for developing important athletic abilities and ultimately may improve sport performance. For example, biomechanical analysis of ground reaction forces suggests that the subjects performing the snatch and vertical jump used similar adjustments in the temporal pattern of propulsive force application for each activity (Garhammer and Gregor, 1992). Other research has investigated the kinetic and kinematic relationship between the hang snatch and the vertical jump. More specifically, ground reaction forces and angular displacements of the hip, knee and ankle joints were assessed. Kinetic characteristics were similar, suggesting weightlifting may be useful for improving jumping power (Canavan et al., 1996). The relationship between weightlifting and anaerobic power performance was previously investigated by Stone et al. (1980), who compared the snatch and clean to the vertical jump and a modified Margaria test. Weightlifting resulted in vertical jump and Margaria power performance improvements. In addition to the role of weightlifting as a strategy for improving sport performance, Barry (1993), in a review of weightlifting research, suggested that investigations focus on issues of internal joint forces, ground reaction force, barbell and weightlifter kinematics as well as analysis of the different phases of the lifts. Research examining differences in ground reaction forces during the snatch performed by weightlifters of differing athletic ability suggests that the rate of force production varies as a function of ability (Funato et al. 1999). Other sources have examined kinetic and kinematic parameters of snatch technique and compared them among athletes of different weight classes and abilities (Baumann et al, 1988). Kuhanen et al. (1984) evaluated the ground reaction forces and electromyography of weightlifters of differing ability. Results revealed differences between the two groups as evidenced by greater ground reaction forces during the first pull of the clean and a shorter duration of the drop under phase of the jerk for the more advanced weightlifters. Research has examined the biomechanical variables associated with weightlifters of differing abilities and phases of weightlifting exercises. However, research comparing different weightlifting exercises is limited. Furthermore, few studies have evaluated weightlifting exercises at varying loads/intensities. Haekkinen et al. (1984) investigated kinematic, kinetic and electromyographic characteristics of the phases of the snatch and clean and jerk between two groups of weightlifters of differing ability levels. These researchers also investigated how these variables were affected at loads of 70, 80 and 90 and 100 percent of their maximum. Results revealed greater ground reaction forces in both groups at sub-maximal loads than at maximal loads. Weightlifting is a sport in which single repetition performance at the highest possible load is the sole determinant of success. However, weightlifting also serves as an effective training mode for those who participate in other sports requiring power. As a result, it is useful to understand how this training stimulus changes as a function of the specific weightlifting exercise, as well as the training load/intensity, so decisions can be made regarding how to best implement these exercises in training. Often researchers have evaluated weightlifting via ground reaction forces and electromyography. However, because impulse is a measure of change in momentum, and thus related to acceleration, it is more an indicator of how well an athlete can generate force over time. Therefore, the purpose of the current study was to evaluate movement impulse and peak ground reaction force of the hang clean and hang snatch at 50, 60, 70, 80, 90% of their maximum and compare the impulse associated with the two exercises.

METHODS: Five male (mean ± SD; age = 21.7±2.3 years, body mass = 90.3±16.0 kg, 1RM squat = 225±28.3 kg), NCAA Division I athletes (track and field, football and wrestling) volunteered to serve as subjects for the study. All subjects used the studied exercises in their regular weight-training regimen. Subjects completed a Physical Activity Readiness-Questionnaire and signed an informed consent form prior to participating in the study. Approval for the use of Human Subjects was obtained from the institution prior to commencing the study. Subjects had performed no strength training in the 48 hours prior to data collection. Warm-up prior to the weightlifting exercises consisted of at least 3 minutes of low intensity work on a cycle ergometer. Static stretching included one exercise for each major muscle group with stretches held from 12-15 seconds. Following the warm-up and stretching exercises, the subjects were allowed at least 5 minutes rest prior to beginning the weightlifting exercises. The order of hang clean and hang snatch was randomly assigned; while the loads progressed from 50% to 90% 1 RM for each exercise. The hang clean and hang snatch are variations of the clean and jerk and snatch. The hang clean consists of quickly and forcefully pulling the barbell from a position just above the patella to the front of the shoulders in one continuous motion. The hang snatch incorporates a wider barbell grip and the quick and forceful movement of the barbell from a position just above the patella to overhead with the elbows fully extended. (Earle and Baechle, 2000). The weightlifting exercises were performed on a 2 cm thick aluminum platform (76 X 102 cm) bolted directly to a force plate (OR6-5-2000, AMTI, Watertown, MA, USA). Ground Reaction Force (GRF) data were collected at 1000 Hz, real time displayed and saved with the use of computer software (BioSoft 1.0, AMTI, Watertown, MA, USA) for later analysis. The force platform was zeroed for the subject's combined body and barbell mass for each lift. Movement impulse was defined as the area under the curve, but above zero during the upward phase of the lifting movement. Peak GRF was the highest value attained during the lifting movement. Statistical treatment of the data was performed using a 2X5 (lift type X % RM) Repeated Measures ANOVA for movement impulse and peak GRF.

RESULTS: Analysis of movement impulses revealed no significant difference between lift types (p=0.73) or interaction of lift type by load (p=0.68) as shown in Figure 1. There was, however, a significant difference (p=0.001) between loads as indicated by % RM shown in Table 1. As illustrated in Figure 1, peak GRF analyses also displayed no differences between lift types (p=0.92) or interaction of lift type by load (p=0.39). However, similar to movement impulse, peak GRF was significantly different (p=0.001) across the range of loads as displayed in Table 2.

DISCUSSION: Only one study has previously evaluated kinetic variables of weightlifting exercises at differing training loads, or percentages of 1 RM. Haekkinen (1984) reported that ground reaction forces were greater at submaximal loads than at maximal loads. These findings are in contrast to the present study which demonstrates that impulse and ground reaction forces are statistically lower at 50% 1RM compared to higher percentages of 1 RM. Furthermore 60% 1RM was less compared to 80 and 90% 1RM; and lower at 70% 1 RM compared to 90% of 1RM. Interestingly, no differences in impulse or peak ground reaction force were found between the hang clean and hang snatch, despite the fact that the hang clean loads were approximately 50 percent greater, on average. These findings suggest other variables such as exercise form and movement velocity mediate the amount of force developed. Therefore it is likely that kinematic variables are important in the expression of impulse and ground reaction force for variations in weightlifting exercises as previously reported by other researchers (Haekkinen et al. 1984, Baumann et al. 1988). Differing methods of lifting the weight, including acceleration of the barbell, would also affect the GRF

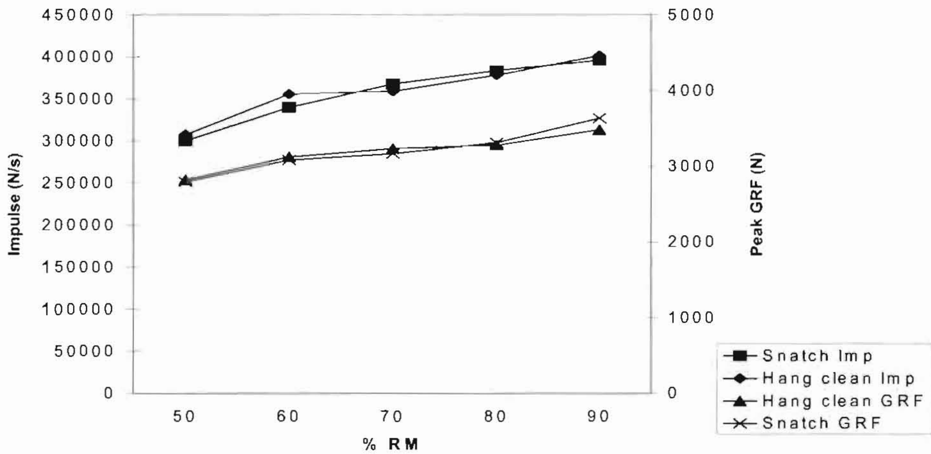

Figure 1. Mean movement impulse for the hang clean and hang snatch at five intensities of 1RM.

Table 1. Movement impulse (mean ± SD) for the hang clean and hang snatch at five intensities of 1RM.

	50% RM[a]	60% RM[b]	70% RM[c]	80% RM	90% RM
Hang clean ($N \cdot s^{-1}$)	307492	355406	358770	378161	401471
	±16297	±44531	±56014	±73370	±87621
Hang snatch ($N \cdot s^{-1}$)	300107	339640	367383	383514	395902
	±48453	±32831	±41521	±78052	±58810

[a] Significantly different ($p<0.05$) from 60, 70, 80, 90% RM
[b] Significantly different ($p<0.05$) from 80, 90% RM
[c] Significantly different ($p<0.05$) from 90% RM

Table 2. Peak ground reaction force (mean ± SD) for the hang clean and hang snatch at five intensities of 1RM.

	50% RM[a]	60% RM[b]	70% RM[c]	80% RM	90% RM
Hang clean (N)	2788.9	3083.2	3165.1	3309.9	3633.3
	±399.5	±586.2	±610.3	±654.8	±579.4
Hang snatch (N)	2818.4	3120.2	3232.1	3275.9	3479.4
	±478.4	±579.0	±545.5	±710.1	±740.5

[a] Significantly different ($p<0.05$) from 60, 70, 80, 90% RM
[b] Significantly different ($p<0.05$) from 80, 90% RM
[c] Significantly different ($p<0.05$) from 90% RM

and the impulse during the lifts. Another possible reason for the lack of difference between the two types of exercise may be the relatively high standard deviations (between 10 and 21% of the mean). This degree of variability is similar to that of the loads lifted during the hang clean and hang snatch, which would explain why peak GRF and impulses were so variable. A larger sample size would also likely result in a decreased standard deviation.

CONCLUSION: Quantifying biomechanical variables during weightlifting exercise serves as one way to evaluate the characteristics of this training stimulus when compared with other physical activities, such as other types of resistance training, running, jumping, and simulated or actual sport performance. Understanding training exercises and the performance of exercises at various loads can assist the clinician in prescribing the proper progression of these exercises for the rehabilitation of injured athletes as well as progressing training for the healthy athlete. Theoretically, increasing from the lower to higher impulse and GRF over the course of the training period, by training at increasing percentages of the 1RM, may prepare participants for the impulses and forces associated with athletic competition.

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